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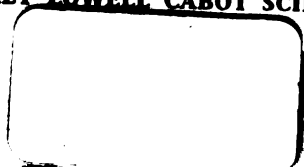
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THE  
BERLIN-ZOSSEN  
ELECTRIC RAILWAY TESTS  
OF 1903.

A REPORT OF THE TEST RUNS MADE ON THE  
BERLIN-ZOSSEN RAILROAD IN THE MONTHS  
OF SEPTEMBER TO NOVEMBER  
1903.

*TRANSLATED FROM THE GERMAN*

BY

FRANZ WELZ, E.E.

WITH AN INTRODUCTION DISCUSSING THE GENERAL  
SUBJECT OF TRAIN RESISTANCE

BY

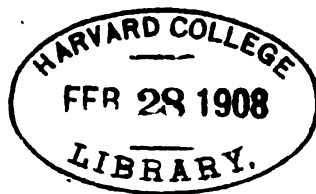
LOUIS BELL, PH.D.,

*Mem. Am. Inst. Elec. Eng.*

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## INTRODUCTION.

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THE tests on the Berlin-Zossen line recorded in this volume occupy a unique place in the history of modern engineering. They represent a deliberate, thoroughly organized and highly successful effort, on the part of a syndicate for research, at solving the greatest problem of twentieth-century transportation; that is, the application of electric traction to very greatly increased railway speeds. The subject has been in the air for more than a decade, and has stayed there, mainly on account of the lack of sufficient experimental data to justify the large investments necessary to such operations. More than a dozen years ago the projected fast line between St. Louis and Chicago brought the subject before the public eye, and had not the ensuing period of extreme commercial depression forced it into the background that line would very probably have become a successful reality. The writer was one of the group of engineers that investigated the project, and the concurrent opinion even at that early day was decidedly in favor of its feasibility. The general features of the equipment as proposed were along the same lines followed by the German experimenters, and the success reached by the latter confirms to-day the auguries of Dr. Adams and his associates. But Fate was against the American enterprise, and the glory of the achievement rests with our German *confrères*.

Moreover, they attacked the task in the right spirit and by the right methods, deliberately expending time and money without hesitation in obtaining on a practical scale full experimental data on the subject before undertaking a commercial equipment. There was little in the prior art of electric railroading to give an adequate standing-ground, for the traction work of ten years past has been assiduously devoted to work with direct-current motors at low voltage and to speeds which, while high compared to the tramway speeds of bygone years, were yet far too low to furnish valuable guidance in the premises. In fact the data from ordinary interurban lines have been for the most part not only of small value, but positively misleading. The enormous speeds contem-

plated in the Zossen work demand concurrent attention to working conductors, motive-power equipment, brakes, car body, trucks, track, and road-bed. The performances of the more ambitious electric roads, which have been merely tramways of a larger growth in construction and equipment, neglecting for the most part all the refinements which demand radical departure from so-called standard methods, have conjured up difficulties at high speed which the event has proved to be of little consequence. The Zossen tests began at the beginning of things with an equipment designed irrespective of tramway precedents and for the special purpose at hand. The earlier trials, to be sure, used the then ordinary track and road-bed of the Prussian State Railways, and found it wanting, as might have been, and probably was, anticipated; but the next step was to reconstruct track and road-bed to meet the new requirements, which insured final success.

The points at issue in the Berlin-Zossen experiments were, first, the feasibility of adequate power supply to a moving train at high speed; second, the determination of the actual power required at such speeds, and third, the construction of roadway and rolling-stock required to make such speeds mechanically secure.

As regards the supply of power to a car at 100 miles per hour and upward over considerable distances there were few precedents to serve for guidance. High voltage on the working conductor was a necessity, and that of itself was looked at askance by the conservative element. Moreover, in the existing state of the art three-phase induction motors were practically the only refuge for motive power, which implied at least two, and actually three, flying contacts. Side-bearing triple-bow trolleys were decided upon, and, as appears from the account of the trials, eventually proved extremely satisfactory. They had the merit of allowing the working conductors to be placed so that the bows would bear along the sides of the catenary curves, instead of having to follow them as in ordinary overhead construction. Moreover, while in the case of a street car, running as it does on a relatively rough track with sharp curves, sidewise oscillation is likely to be troublesome if one tries to use a side trolley, at these very high speeds oscillation must for the sake of safety be kept down to very moderate limits by careful design of trucks and roadway, and the side bearing becomes relatively much easier than an underrunning bearing. The trolley as finally evolved is most ingenious, especially in respect to the air pressure vanes adjusting the bearing pressure to the exigencies of the speed.

The results obtained from it seem to have been such as to leave no doubt whatever of the adequacy of the apparatus for taking off without trouble ample current for the heaviest work required in operating up to 120 or 130 miles per hour. For such a case suspended wires are obviously much simpler than any third-rail construction, which is enormously difficult to insulate for any voltage high enough to be of use in the class of work here attempted. The only direction in which a material simplification could be found is that toward single-phase distribution whether used directly or reconverted on the car. Of this the Zossen experimenters speak hopefully but guardedly. Certainly it would require motors advanced very far beyond anything as yet probable to allow of duplicating the admirable performance of the three-phase induction motors with which the experimental cars were equipped. It is enough, at all events, that the supply system worked smoothly and effectively as there constituted—a change to single-phase operation would merely simplify it in a way obviously advantageous, but not necessary from the standpoint of successful operation.

As regards the motors enough experience had been acquired to make their performance substantially a certainty in advance, the only material question left being whether they were of adequate output for the work in view. In point of fact the motor equipment proved not only amply large, but easily capable of far greater acceleration than was attempted. To avoid undue calls upon the commercial station which furnished the power, the acceleration was normally kept at about 0.5 to 0.6 foot per second per second, which called for about 500 H.P. in excess of that required for continuous runs. This allowed the cars easily to reach a speed of 100 m.p.h. in some six or eight miles, which was considered ample for the class of work toward which the experiments were directed. Retardation by brakes was relatively prompt, the cars being brought to rest from speeds between 100 and 110 m.p.h. in a little less than a minute and in a space of about seven-eighths of a mile. The general equipment of the cars was considerably improved over that used in the trials a year or so previously, particularly in the facilities for exact determinations of power and speed, so that the records of 1903 are far fuller and more complete than the previous ones, and the data obtained are correspondingly more valuable.

The determination of the power required for very high speeds was perhaps the most important function of the Zossen tests, since not only was it a quantity very imperfectly known, but opinions were current even among engineers who ought to have known better that the air and track resistances would rise to a

prohibitive point long before the projected speeds were reached. These judgments were the natural results of reckless extrapolation from uncertain data, and have been completely discredited by the figures actually obtained, which are themselves materially higher than would have been reached had the car-fronts been shaped rigorously with regard to minimum air resistance, as the account of the work clearly shows.

The whole subject of train resistance at high speeds has been involved in great uncertainty; and while the Zossen tests have gone far toward clearing up the difficulties, particularly in furnishing at last a reliable value of the coefficient of air resistance, much work still remains to be done.

The energy spent in pulling a train over its track may be roughly divided into five elements: work against gravity; work of acceleration; internal resistance (i.e., that due to friction within the rolling-stock); external resistances, due to interaction between rolling-stock and track; and air resistance. Of these several items the first two, as such, are pretty definite in character and can be figured in a given case with reasonable precision. The last three are extremely hard to separate and have been the source of many difficulties.

The internal resistances are due mainly to rolling friction at the journal-boxes, but also to friction at every point in the chain of rolling-stock where there is lack of rigidity. The cars sway and grind on their supports, the bogies and couplings writhe, and at every point where there is flexibility there is a chance for the waste of energy. In cases where there is considerable vibration these minor sources of loss may aggregate a very perceptible fraction of the total internal resistance, quite enough at least to vitiate conclusions based on the theory of ordinary rolling friction at the journals. For a given car the theory of bearing friction as developed by Thurston and others would indicate a resistance increasing directly with the speed. The other factors in the internal resistance certainly are not so simply related to the speed. On the contrary they may vary in a very erratic manner and are dependent in no small degree on the contour of the track and the distribution of the weights in the rolling-stock itself. Above certain unknown values of the speed they may increase suddenly at an extraordinary rate and may react on the external resistances in a very serious manner. In the various series of tests on the Zossen line these facts came out in a most striking manner. On the earlier track used it was found that at 80 to 90 miles per hour a condition was reached in which swaying and jumping of the car became so great as to involve danger. At this point not only

was the internal resistance sharply increased, but the external resistance likewise, and neither in any simple way. It would seem probable from the later experiments that much depends on the proper distribution of the weights, and in fact the beneficial effect of counterbalancing in the motor-car was very striking. Really one of the most significant facts brought out in the experiments here recorded was the necessity of careful design of the trucks to insure smooth running at high speeds, and it must be remembered that when a car does not run smoothly both the interior and exterior resistances will increase. With all conditions favorable the internal resistances are the smallest of those which affect a high-speed train, but under certain conditions they may directly and indirectly cause no small amount of trouble.

The external resistances of a train are those which exist as between the rolling-stock and the track. They include the various reactions between the wheel and the rail on which it runs, not only metallic friction, but the effects of roughness in the track and of displacements in the road-bed. In fairly long trains at moderate speeds on good track the external resistance is not large, but, large or small, it is a very uncertain variable. Its factors in the main consist of pure friction between wheel and rail, flange friction, and resistances not included in those ordinarily charged to gravity, but due to pulling the train over initial or impressed roughnesses in the track. There is also probably a certain grinding friction between the driving-wheels and the track, even when slipping in the ordinary sense is very slight. Certainly pretty strong evidence exists of a marked difference in the effect of rolling- and of driving-wheels upon general tractive effort.

Now broadly these elements of resistance tend to increase with the speed, but taking them one by one it is easy to see that so simple a conclusion is unsafe. The ordinary friction of the rolling-wheels probably does vary with speed, but such friction as is due to the bite of the driving-wheels must also tend to increase with the increase of the total tractive effort itself. Flange friction, on the other hand, depends largely upon accidental conditions, such as lateral wind pressure, the swaying of the cars, and the contour of the track. As a whole it is likely to increase as the first power of the speed rather than as any other power, but it may almost disappear at any speed whatever.

The track resistances are likewise somewhat erratic and difficult of analysis. As a matter of experiment the fact stands out that in very many runs at high speeds the apparent track resistances have been very low indeed, even

down to 8 lbs. per ton, or less, at speeds above 75 miles per hour. Any larger estimate would fail to leave room for the known values of atmospheric resistance. In these latest Zossen tests, even at speeds a little in excess of 100 miles per hour the total resistance of a heavy sleeping-car, used as a trailer, proved to be a trifle below 16 lbs. per ton; so that if the track resistance be considered a linear function of the speed, the coefficient at low speed determined by the data just given would be far too small to fit the direct experiments, of which there are many. There is a strong probability, amounting in fact almost to certainty, that the external resistances, especially those due to the track, pass through a maximum or maxima, and may actually be less at low and at high speeds than at some intermediate point.

In fact in Plate XV*a*, wherein the total friction losses are plotted as function of the speed, there is actually shown a greater rate of increase at low speeds than at high, with a minimum slope between 60 and 70 miles per hour. As certain of the total resistances undoubtedly do increase steadily with the speed, certain others must decrease in order to give the curve the form observed.

With the means yet available for separating the various factors of resistance it is very difficult to determine the nature of such variations as these. It is, however, quite conceivable that in the yielding of track and road-bed the absolute duration of pressure may enter as an essential element. In such case it may be that a train moving at the rate of 100 feet per second, or more, may virtually be dealing with a smoother track than at lower speeds. In the case of fairly long trains, too, the internal resistances due to swaying may become less prominent at high speed. In this connection it is a matter of common observation that on a given line the running at high speeds often seems relatively smoother than at low speeds.

It has been customary to put the train resistances other than air resistance in the general form

$$A + BV,$$

*A* being an absolute term irrespective of speed, and *B* a constant coefficient of the speed term. As a matter of experience such formulæ have been successfully applied to the total resistances, including air pressure, over fairly wide ranges of speed. Such are the train formulæ of Sinclair and Vaucrain, which are soundly based on experiments up to, say, 60 to 70 miles per hour. If *B*, considered as representing the general resistances other than air pressure, is really a variable,

as these latest tests would seem to unite with other evidence in confirming, the sufficiency of these simple formulæ, within limits, in spite of the known term in  $V^2$  due to air resistance, is explained. For the diminution of  $B$  at moderately high speeds would then tend to compensate for the increasing air resistance and would tend to bring the formula into accordance with the experiments.

By far the most important technical result, however, of the Zossen tests is the determination of the air resistance. This has been the bugaboo of ultra-conservative engineers in considering the question of high-speed railway service. In nearly all the earlier formulæ in which  $V^2$  has appeared its coefficient has been very much larger than is now found to be correct; and as a result, while these formulæ gave fair results at moderate speeds, they broke down entirely at high speeds. For example, Smeaton's value for air resistance at 60 miles per hour is more than three times that found in the Zossen runs, and Hagen's, derived at better speeds, is too large by fifty per cent. The result of these errors was to give an altogether exaggerated idea of the power required to drive trains at high speed. The typical modern formula for train resistance has taken the form

$$A + BV + CV^2,$$

and the vital point to be determined has been the coefficient  $C$  for a normal plane surface. The Zossen experiments were carefully planned with respect to the determination of this quantity, and the results thus obtained are probably by far the most trustworthy yet reached. The experiments on this matter with moving trains are not easy on account of various factors which have to be eliminated, but from a practical standpoint they are far more reliable than those made with whirling bodies, which upon the whole have given very discordant results. The net result of the Zossen tests was to give 0.0052 as the coefficient of  $V^2$  when the pressure is taken in kilograms per square meter, and the speed in kilometers per hour. The value used by artillerists for projectiles at moderate velocity is .0051 when reduced to the same terms, so that the facts thus derived from two entirely different lines of experiment are in substantial agreement. The corresponding coefficient for square feet, pounds, and miles per hour is approximately .0027. It should be noted in this connection that no other experiments with actual cars have reached anything like the velocities recorded at Zossen, so that these values are the only ones not subject to the errors of wide extrapolation.



A most essential feature of any consideration of the air resistance to high-speed trains is the possible effect of shaping the head so as to reduce the coefficient of  $V^2$ . It has of course long been known that a wedged-shaped or parabolic head would very materially reduce resistance. Detachable "noses" were therefore used in the Zossen tests with some success, although they were not so arranged as to be fully effective. They were, however, sufficient to show that with a fairly rounded front the resistance coefficient lies a trifle below .0025. The difficulty in estimating the really effective area of so complicated a shape as a car-front is the cause of the remaining uncertainty, especially when one tries at once to include front and lateral resistances. There are, also, certain air-resistance effects at the stern, so to speak, of a train which may very possibly be reduced by proper shaping.

But these refinements, while assuredly of some importance in future work, do not bear immediately upon work now in progress. They must be considered, however, as part of the general theory.

The main trouble in reducing the data now at hand to working formulæ lies in the general desire to get into simple terms a thing which is essentially complex. Most train formulæ have been in terms of pounds of tractive effort per ton of weight. So long as the air resistance was but a small part of the total, either from low speed or from dealing with long and heavy trains, a ton coefficient was measurably easy, but air resistance as such is not a question of weight but of area, and must be so treated. Ordinarily a reduction to terms of tonnage is made by using square feet of exposed surface per ton in the appropriate coefficient. At very high speed the air pressure is in so far predominant that it would seem wiser to treat it separately. The results obtained in the Zossen runs, for instance, take on a most extraordinary appearance when put into the usual shape. In powers of  $V$  the curve  $XVa$  becomes to a close approximation

$$4 + .02V + .0027V^2.$$

Of course some modification of the coefficients can be made without throwing the computed resistances wide of the experiments, but the essential facts are that the coefficients of  $V$  and  $V^2$  are much lower than usually assumed. In particular the frictional resistances, owing to the weight of the car and the careful work done on the trucks to insure smooth running, are apparently extremely low, less in fact than 7 lbs. per ton. The resistance for a trailer already noted shows both the effect of lacking proper running balance and the undesirability

of using formulæ of the tonnage type outside of a very narrow range beyond the experimental case. The addition of a single trailer throws the formula out of court, and a modification of the formula to fit this particular trailer would again become useless with a small variation of conditions.

In other words, no simple formula can be made to express the widely varying facts. If the whole range be cut up into short sections, short formulæ can be made applicable. Even purely linear formulæ work well if the range of speed is not great enough to make the curvature of the air-pressure line prominent. For example, in Plate XI, between 90 and 130 miles per hour, a straight line can be made to fit the experimental points nearly as well as the present curve, and the same fact is true of shorter distances elsewhere on the curve. If a single general formula is desired, it can most easily be obtained by making it apply to the total resistance and building it up of a sum of terms relating first to tonnage and second to air resistance, both sets probably including the number of cars. It is quite possible that such a generalization might be made, but in the present state of knowledge it would be a most formidable task.

The hints on train design given by the Zossen work are very important where high speeds are to be considered, and should be closely followed up in all attempts at high-speed work. Smooth running is essential not only to low resistance, but from every point of view, and this can be secured only by close attention to the details of the cars and trucks, as well as track and road-bed.

The additional experimental facts most needed for the study of train resistance are, first, those which will give a clear view of the resistances aside from air pressure, and second, those which relate to lateral wind pressure. These at present must be taken care of by a sufficient factor of safety in the motive power. The great essential thing shown by the Zossen tests is that it is entirely feasible to operate electric trains at speeds very much greater than those now usual, without demanding an unreasonably large amount of energy and without any radical departure from existing conditions in roadway or in rolling-stock. It is a long step, however, from this demonstration to the practical operation of high-speed trains, not on account of the technical difficulties of the case, but by reason of its commercial aspects, including the hesitancy of existing railroads, in inaugurating a high-speed campaign with electricity or any other motive power.

An interesting and valuable feature of the present discussion is the working out in detail by each of the great electric companies which participated in the Berlin-Zossen work of a definite project for the commercial application of

the results. Each project deals with a line between Berlin and Hamburg planned for a schedule speed of about 100 miles per hour, and each is based upon the use of methods and apparatus already tried: three-phase distribution to motor-cars similar to those already operated, with cars of the existing vestibuled type used on the through trains, fitted with trucks modified in view of the tests so as to secure smoother running. Whatever improvements may later be made in methods will therefore tend to improve the situation.

Of the two the Siemens-Halske plan is the more conservative in assuming only a moderate traffic and planning for a single-track road with a turnout at its middle point, operating trains on a two-hour schedule, and entering the termini over existing tracks. A modification of this project provides for double-tracking the line and running an hourly schedule. The main difficulty in formulating a plan for such work lies in the practical impossibility of making a just estimate of the probable traffic. The route of the line would certainly be the most productive in Germany, on account of the size and great commercial activity of the termini. It is long enough, too, to bring out at least some of the characteristic advantages of high-speed work, although a hundred miles, greater run would make them more prominent. That such a line would catch substantially all the express-train through traffic now existing admits of little doubt, and it is altogether probable that a regular two-hour service at the speed proposed would do much more than this.

For there are generally to be found many passengers who would travel by the slower trains to gain an advantage in fare, but to whom the great saving in time by the fast electric line would prove of value enough to encourage them to patronize it. In addition the two-hour service regularly maintained would attract many passengers who for one reason or another now start from the termini at times when no express service is available. One million passengers per year would not seem an excessive estimate of the traffic promptly available, and the single-track estimate of Siemens-Halske shows a modest but still reasonably good profit with traffic of little more than half this amount. It is somewhat questionable whether an hourly service would attract enough extra traffic to compensate for the cost of double-tracking the road and increasing the plant, but the system would doubtless grow to it. The plan of the Allgemeine Elektrizitäts-Gesellschaft is more ambitious, including a double-track line with independent entrances into the termini and a half-hourly service. The independent entrances strike one as rather necessary in order to maintain a free service and

to keep up the schedule, but the value of the half-hourly schedule as an additional traffic-winner is not so clear. If a two-hour service with extra trains during part of the day could be arranged for a single-track line with its own entrances into Berlin and Hamburg, the receipts would probably bear a larger proportion to the investment than in any of the present projects. These are, however, matters that can be more advantageously discussed in the light of further knowledge of the traffic possibilities. Not much light is thrown on the problem by the gains in traffic on existing electric lines, for the class of service is something altogether different from anything yet attempted.

In our own country there are several very promising opportunities for fast lines. Boston and New York, New York and Washington, Chicago and St. Louis, are all routes amply able to furnish suitable density of traffic. A line from New York to Chicago, although involving a very large investment, would still be a very exceptional winner of traffic, both between these termini independently and as part of the route further westward.

It is hard, however, to see how some of these lines could be built in face of the inevitable opposition from the existing lines which would suffer by their competition.

From an engineering standpoint the difficulties of this fast service, thanks to the work on the Berlin-Zossen line, are no longer formidable. The way has already been clearly shown, and while there are still numerous minor problems to be solved, they are of a rather commonplace nature. It is a tremendous gain that the broad features of the work have been already sketched out, and it is not putting the case too strongly to say that a project for hundred-mile-an-hour service has to-day nothing of difficulty to stagger the competent engineer. The matter has become merely one of dollars and cents, and granted the possibility of getting available rights, the commercial outlook is not forbidding. This is much to say of so revolutionary a change in methods of travel, and yet it is fully justified by the facts. Americans are persistent travelers, and delay is irksome to them, so that a really fast line in this country would gather traffic in a measure possible in no other country. The work awaits the man with dash and courage enough to carry it through.

Meanwhile one can hardly overestimate the splendid work that the Studien-gesellschaft has done for Germany and for the world in pushing to a triumphant conclusion what may be fairly rated as one of the most imposing scientific investigations in history in its bearing on human enterprise. The Atlantic cable

is the single great experiment of commensurate importance; and while we now see the cable's value clearly, we can hardly yet appreciate the revolution in communication that would be wrought were the Berlin-Zossen tests pushed to their legitimate conclusion. In the fullness of time the work of the Studien-gesellschaft will bear fruit worthy of its promise, and the world will realize the debt it owes to the unwearied energy of this brilliant and determined group of engineers and captains of industry.

LOUIS BELL.

## BERLIN-ZOSSEN ELECTRIC RAILWAY TESTS.

---

LAST year, from the beginning of September to the end of November, the "Studiengesellschaft" carried on successfully a third series of high-speed railway tests on the Military Railroad. These numerous and successful test runs have made it possible to make exact measurements and gather important data regarding high-speed service. The following report contains an account of: (1) The preparations for the tests; (2) the improvements of the road and of the rolling-stock; and (3) of some new measuring instruments. The report also describes the method of procedure and gives the results of the test runs.

### I. PREPARATORY WORK.

#### 1. Construction of the New Road.

The Ministry of Public Works agreed to aid the "Studiengesellschaft" in their work by loaning ties, rails, and the iron material used in the construction of the track. The Minister of War offered to lay the new tracks, and, if necessary, to restore the old tracks for a nominal sum after the completion of the tests. The "Studiengesellschaft" had, therefore, nothing to buy except the ballast and the supports for the guide-rails, which amounted to about \$59,450. As this amount was not available, the "Studiengesellschaft" petitioned the Minister of Public Works for a loan of \$71,380 in addition to the loan of material. This petition was granted by the Minister after it had been approved by the State Representatives, and it was, therefore, possible to start the construction of the new track in the spring of 1903. Commencing with April 21st the following material was delivered:

20,000 cubic meters (706,400 cu. ft.) crushed stone for ballast.

34,800 ties.

46,193 meters (151,800 feet) of steel rails.

34,445 meters (113,050 feet) old rails, used as guide-rails.

1,588 metric tons (1,752 tons) of iron materials.

6 track switches.

60,000 supports for the guide-rails.

As a result of extensive tests made by Railroad Director Schubert on different materials, crushed stone from the Sproitz stone quarries, in lower Silesia, in the sizes of 7 to 10 cm. (2.75 to 3.93 inches) diameter, was used for ballast. The pine ties were impregnated at the works of Rütgers, in Finkenheerd, with chloride of zinc and tar, the latter containing a small part of carbolic acid. Beech pegs were screwed into the ties, according to the method of Collet, as shown in Figure 1.

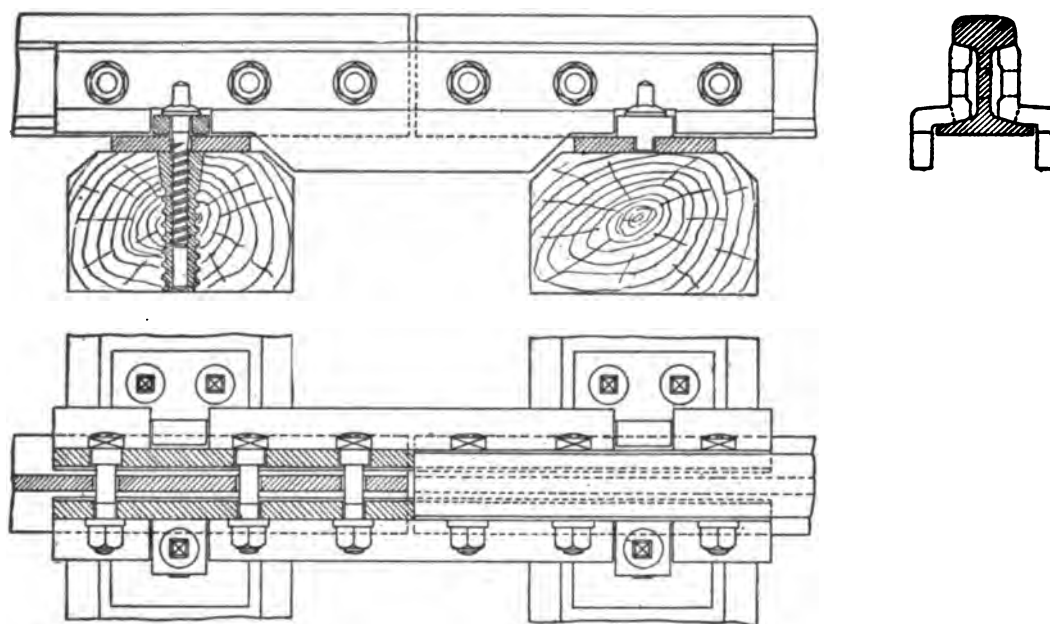


FIG. 1.

The rails of Bessemer and Martin steel, profile 8 of the Prussian railways, were 12 m. (39.36 feet) long and weighed 41 kg. per running meter (27.49 lbs. p. ft.), while the rails heretofore employed weighed but 33.4 kg. p. m. (22.39 lbs. p. ft.). As guide-rails, old rails, profile 6 of the State railroads, were employed. The supports for the guide-rails were of cast iron and weighed 11 kg. (24.2 lbs.) each.

Thanks to the excellent management of the Royal Railroad Administration at Berlin and the Administration of the Military Railroad, the acquisition and the delivery of the material during the reconstruction was brought about in time so that only one interruption of a few days took place, and that on account

of lack of ties. The reconstruction of the section Marienfelde-Zossen, 23 km. (14.28 miles) in length, was done by the railroad corps during the time from May 11th to August 28th, 1903, without any accident and without interrupting in the least the service of the Military Railroad.

The line to be reconstructed was divided into three sections of equal length, and each one of the three regiments of the railroad brigade was charged with

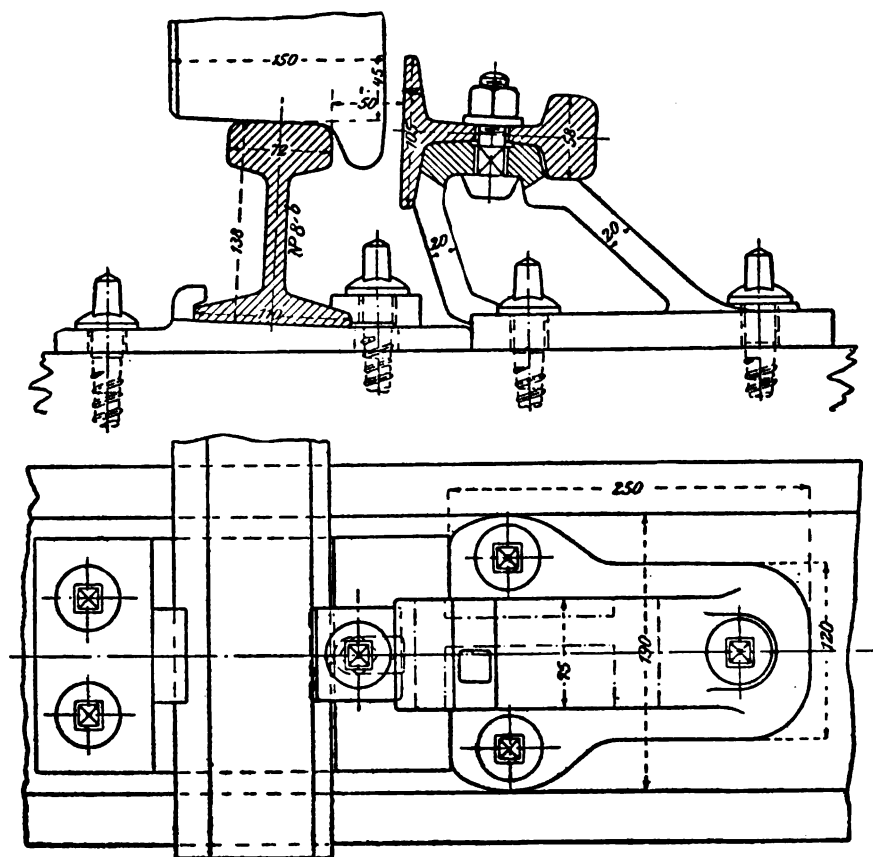


FIG. 2.

the reconstruction of one of these sections, which had to be finished within a pre-determined period of time. As the Military Railroad possessed only one track, and as the service could not be interrupted, the work had to be arranged in such a way that all preparations, such as removing the dirt from the ties, distributing the iron material, loosening the exterior tie-bolts and also one screw in each bed-plate, and the leveling of the new reconstructed section, had to be done during the day, while the removal of the old track and the laying of the new had to be



done in the night. A man working 12 hours a day averaged, according to the conditions of the old track, from 1.486 to 1.642 m. (4.888 to 5.389 feet) of reconstructed track per day. The reconstruction had to be executed partially under very unfavorable weather conditions and under very great restrictions as to space, on account of the proximity of another railroad. The railroad regiments deserve great credit for the excellent work, the accomplishment of which was made possible only by a thorough and proper preparation of all the details for the reconstruction by the Administration of the Military Railroad and by the indefatigable activity of all officials of this body, and especially of the Service Inspection Department No. 1. The type of construction of the new road is shown in Figures 1 and 2. Eighteen ties were used per rail length and were laid with 685 mm. (26.96 inches) between centers, except at the rail joints, where the distance was reduced to 530 mm. (20.87 inches) and 600 mm. (23.62 inches) respectively. In order to make the track construction more safe all the ties were equipped with hook-plates (Figure 2). Upon the request of the Georg-Marienhütte, of Osnabrueck, at kilometer post 18.5 a special track construction employing capping joints was used for a length of 250 m. (820 feet). The new track weighed, exclusive of the ties and guide-rails and fixings, 117.48 kg. p. m. (79 lbs. p. ft.), whereas the guide-rails with supports and fastenings weighed 110 kg. p. m. (74.51 lbs. p. ft.). As only a moderate speed was maintained at the beginning and at the end of the test track, the guide-rails were omitted upon these parts of the track, and only the line from kilometer post 10.5 to kilometer post 27.5 was equipped with these rails. Figure 3 shows the beginning of the guide-rail line near Lichtenrade. At the crossings, the part of the guide-rail which projected above the rail was cut down 25 mm. (1 inch) in order to facilitate the passing of the wagon traffic. The two switches in the main track at the Rangsdorf station were taken out during the test period, but were arranged so that it was possible to put them back during a night pause if occasion should demand. In order to safeguard the switch in the main track at the Mahlow station, special guide-rails were used, the arrangement of which is shown on Plate I for the switch-point and on Plate II for the frog of the switch. These safeguards were manufactured in the State Railway shops at Guben. The parts of the 'guide-rails which are drawn in the above figures allowed the car to run through the switch in the direction of the main track only. These parts were detachable and were put on every day before the beginning of the tests and taken off after the tests were finished. The putting on and the taking off was done by

the station laborers in 12 minutes for each switch. This arrangement made it possible to use the switches for the regular service at a moment's notice and at



FIG. 3.

the same time allowed the high-speed cars to run through with as much safety as on the open stretch.

## **2. Changes in the Overhead Lines.**

In the first test year and likewise in the last the trolley gave no trouble up to speeds of 160 km. p. hr. (100 miles p. hr.), and the collecting of the current by the sliding bows from the trolley wires took place without difficulty; but at

higher speeds the sliding bows caused a marked swinging motion of the trolley wires, which motion was carried over to the poles. It was found that this could be remedied by fastening the poles with guy-wires. During heavy storms the swinging of the wires was so great that they touched one another and the test runs had to be stopped. In order to avoid such disturbances it was necessary to place the poles nearer together.

At the beginning of this year's tests, disturbances occurred several times by birds sitting on the lightning-arresters and grounding-devices and causing a short-circuit, which was followed by the blowing of the fuse at the power-house.

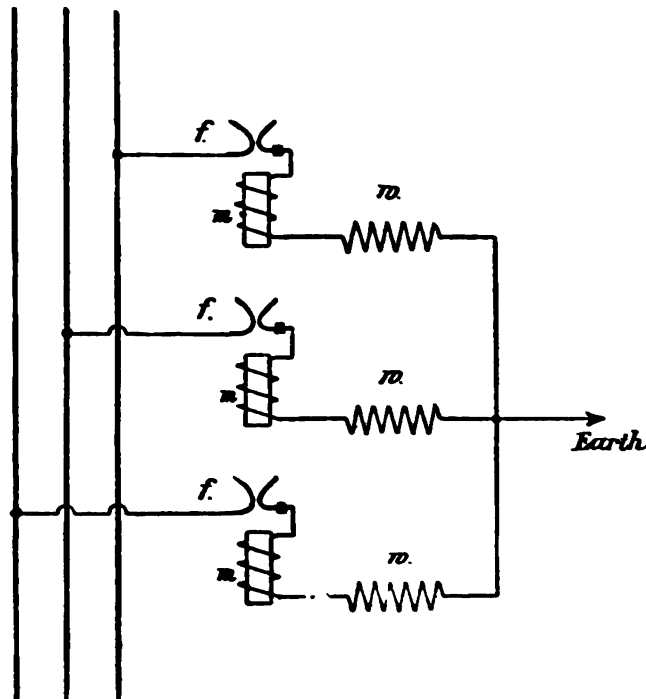


FIG. 4.

These troubles were avoided by inserting an automatic oil circuit-breaker at the distributing-pole, causing an interruption of the current if it exceeded a certain amount. A man was stationed at this point to read the instruments, and to watch this oil-switch and throw it in again when it had been actuated.

In the first installation the feed wires were carried across the State Railroad and the Military Railroad at Marienfelde in a cable laid under the tracks. At the points where the cable was connected to the bare feed wires and to the trolley-line, excessive voltage was observed several times during the tests. It is sup-

posed to have been caused by a variation in the load in the overhead line, which produced resonance effects at these points. These effects caused in one case a short-circuit between the lightning-arrester and the corrugated iron wall of a cable-box at Johannisthal, and in two other cases the cable at the feeding-point at Marienfelde was destroyed. In order to prevent a repetition of such disturbances bare wires were used instead of the cable for the crossing of the State and Military Railroads. Besides, voltage safety cut-outs of the "Allgemeine Elektrizitäts Gesellschaft" were installed at the feeding-point for the purpose of discharging the excessive voltages in the overhead lines from one phase to the other or to the ground. These voltage safety cut-outs (Figure 4) consisted of an adjustable spark-gap, *f*, with a magnetic blow-out, *m*, and a water rheostat *w*, inserted between the safety device and ground. The above described improvements gave excellent results and thereafter no other disturbances occurred in the service. As an example of the excellent working of the grounding-device and of the automatic circuit-breaker, the following incident may be cited: One of the trolley wires which was carrying 40,000 volts, broke and fell upon the foot of one of the employees without giving him the slightest shock, showing that the wire had become dead immediately after the break had occurred.

### 3. Electrical Equipment of the Cars.

The sliding bows, which had given good results up to a speed of 160 km. p. h. (100 miles p. hr.), frequently left the trolley wires at higher speeds, so that the steady feeding of the current to the car, which is absolutely necessary in order to attain the highest speeds, was interrupted. In so far as these defects were caused by slight unevenness and by the swinging of the trolley wires, they were remedied by guying the poles. But the principal cause of this unsatisfactory working of the sliding bows was their elasticity and the comparatively large mass of the sliding pieces and of the parts connected to the latter. At these high speeds even the smallest changes in the direction of the line or the least swinging of the car gave to the sliding bows an impulse in the transversal direction of the track, so that they were thrown off several inches from the trolley-line. After several test runs had been made with car S, with different constructions of the spring devices and of the sliding pieces, one construction, designed by Siemens & Halske, proved to be the best. In this construction the sliding

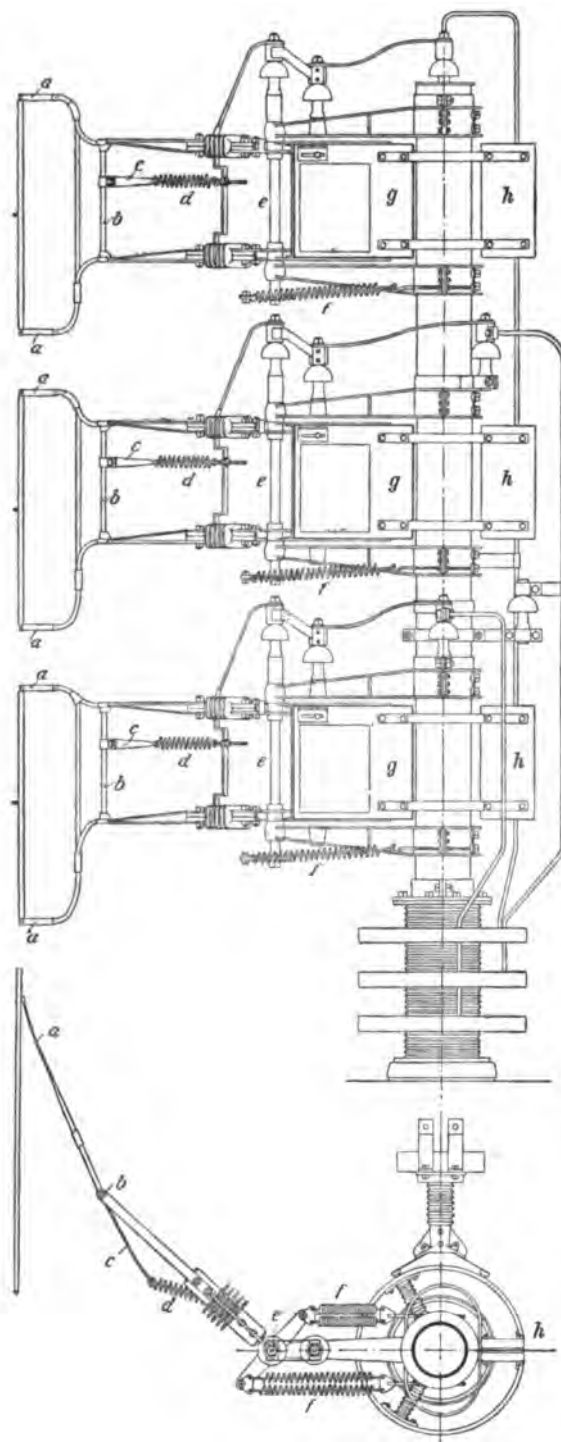


FIG. 5.

piece consisted of aluminum and was protected from too rapid wear by a brass tube  $1\frac{1}{2}$  mm. (0.06 in.) thick being pushed over and enclosing the aluminum. The weight of the former sliding piece was reduced by this construction from 850 g. (1.87 lbs.) to 600 g. (1.32 lbs.) while retaining the same strength. A light steel

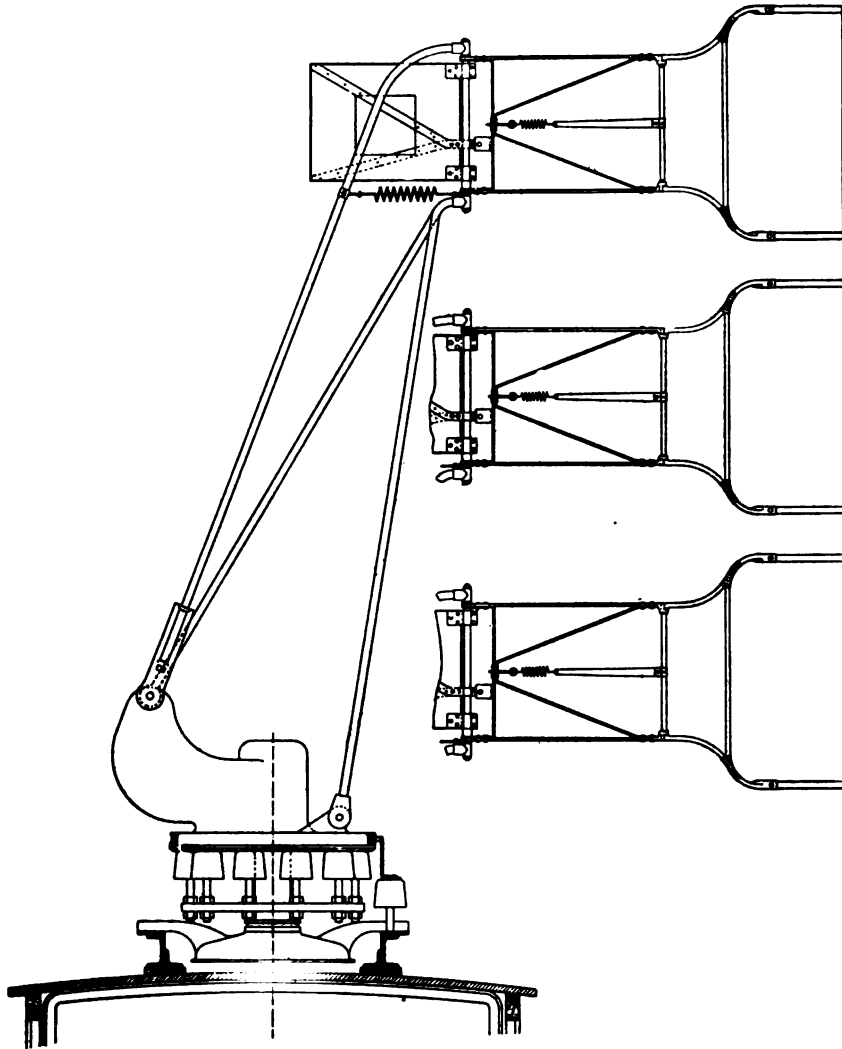


FIG. 6

tube construction was used throughout in the moving parts of the trolley. Besides this, the springs pressing the sliding bows to the trolley-lines were made more elastic and adjusted in such a manner that the sliding pieces were pressed to the wire with a pressure of only  $2\frac{1}{2}$  to 3 kg. (5.5 to 6.6 lbs.). This triple spring arrangement is shown in Figure 5. The sliding pieces are held by long and thin

blade springs, *a*, which are connected to the axis *c* by means of tubes. The axis is held by another combined spring device, *c* and *d*, and the whole front part turns around the axis *e* and is held in equilibrium by the spiral springs *f*. Originally vanes were used with these sliding bows, thus utilizing the wind pressure at the high speeds to keep the trolleys on the wires. At the higher speeds these vanes proved to be too small, so that each sliding bow was equipped with another vane, *h*, on a longer arm in order to make the air pressure more effective. The sliding bows in their final form collected the current satisfactorily at the highest speeds,

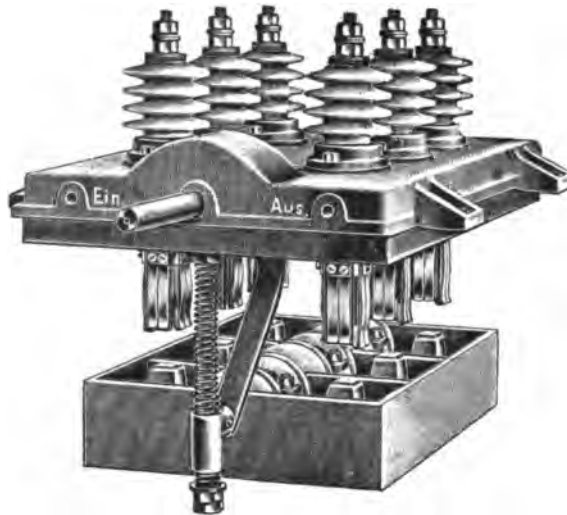


FIG. 7.

and they were held to the trolley-line with an absolutely uniform pressure so that there was no sparking and the wear was kept within reasonable limits. After these changes had proved to be successful with car S, the sliding bows of car A were also reconstructed along the same lines, and equally good results were obtained (Figure 6). The switches which were used in car A in the first series of tests were replaced by oil-switches. One of these oil-switches was installed in each end of the car and served for cutting in and out the high tension. Besides, each motor was equipped with a special oil-switch in order to enable the motorman to cut it in and out independent of the others, and to run the car with any number of motors. The possibility of cutting out each motor separately had the great advantage of reducing the fluctuations of current in the transformers, on the cars and in the power-house, and the excessive voltages produced by these fluctuations of current were kept very low. The construction of such an oil-switch is shown in Figure 7.

The water rheostat of car A, mentioned in the first report, had already undergone some changes last year. These were made to increase the rate of the water circulation and the effect of the cooling-coil. The rheostat for the four motors, in its present construction, is shown on Plate VIII and VIIIa in longitudinal and cross section. The electrodes are mounted stationary in the apparatus, and the regulation of the resistance is obtained by changing the water-level in the tank. The water, to which a solution of sodium carbonate has been added, is maintained in permanent circulation by centrifugal pumps, and is kept at a low temperature by cooling-coils. The rheostat contains 1200 l. (317.04 gallons). At the highest level the resistance of the rheostat equals that of the armature. If, therefore, the metallic short-circuiting device is put in operation, a fluctuation of the

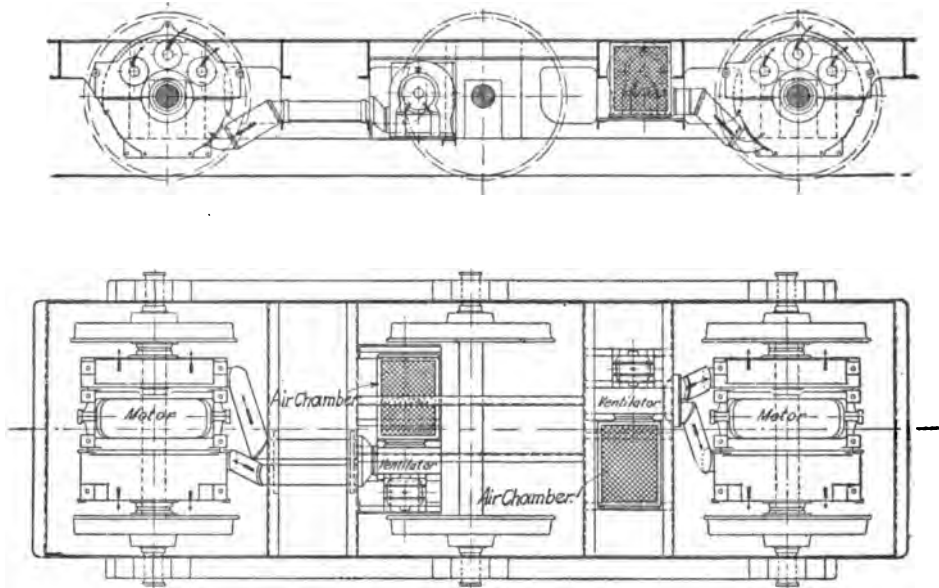


FIG. 8.

current takes place, which corresponds to the motor load at any given time. In order to avoid these fluctuations, it would be advisable to insert two or three notches with metallic resistance before the short-circuiting device is put in operation. Aside from that, the rheostat worked satisfactorily. It allows a very smooth starting, is comparatively simple in construction, thus necessitating little attention. Lastly, an artificial cooling device for the motors was installed on car A, which installation presented no difficulties, as all had been prepared in advance. The object of this arrangement was to study the effects of artificial air-cooling on large motors. The arrangement is shown in Figure 8. Each



motor is provided with an electrically driven ventilator which sucks in air that has been cleansed of dust and then forces it into the interior of the motor. The air leaves the motor on the front side, as indicated by the arrows. This arrangement has proved to be very efficient, but would not have been necessary in this case, as the motors did not become excessively heated under ordinary service load.

The connections in car S were changed, inasmuch as the primary windings of the motors were not thrown in simultaneously as before, but separately. The motors of this car, which had not been provided with artificial cooling, showed but slight heating on the daily runs. The temperature of the transformers of both cars also remained within limits of good practice. In considering this and the fact that during the short time of two to three hours, the duration of the daily tests, the cars had to start from four to six times, there is no doubt that the electrical equipment is fit for continuous service when long distances are to be made at high speeds without stops.

No other changes in the electrical equipment of the two cars were necessary, as in this form entirely satisfactory results were obtained.

#### **4. Reconstruction of the High-speed Cars.**

At the meeting of the Technical Committee, on April 10th, 1902, the two electrical firms who were interested in the "Studiengesellschaft" declared their willingness to build, at their own expense, two new and completely equipped eight-wheel swivel trucks for each one of the high-speed cars. The Technical Committee accepted this offer with many thanks, and ordered its Executive Committee to work out new plans for the swivel trucks in accordance with the specifications of the electrical firms. This was done, and it was found that an eight-wheel swivel truck had to have a distance of 6 m. (19.64 feet) between wheel centers in order to give sufficient room for the supporting springs, the equalizing levers, and for the braking apparatus. Swivel trucks of such a length could not be built-in under the high-speed cars without completely reconstructing the whole lower part of the car. As the latter change was not intended, it seemed to be more suitable to reject these plans until an entirely new car could be procured. The Technical Committee agreed to this, and approved at its meeting of March 9th, 1903, the plans for a six-wheel swivel truck with 5 m. (16.4 feet) between axles, the design of which was based upon experience gathered from the tests which were made in the fall of 1902. These trucks were then built in the shops of "van der Zypen & Charlier," according to the

drawing on Plate III, and the high-speed cars equipped with them were put in service in September, 1903. The new swivel trucks correspond in their construction to the specifications given in the report of the fall of 1902, on page 39, and the brake arrangement to the principles laid down on page 35 of the same report. Their side frame consists of single plates of 15 mm. (0.59 inch) thickness, which, as shown in Figure 9, are bent over on the upper and lower sides.

At the lower intersection as well as at the journal-boxes the frame-plates are strengthened by angles and plates. The springs and equalizing levers are placed on the outside of the frame. The car body is carried by eight pans, four on each truck. These are fastened between the center axle and the exterior axles upon the truck frame and the cross-girders, in the plane of the wheels. This arrangement, which was recommended by Privy Counsellor von Borries, takes the load off of the middle bolt and gives it at the same time a play of 30 mm. (1.18 inches) on each side of the center, in a line at right angles to the track; the bolt is held in the middle position by flat springs the tension of which at rest is 1500 kg. (3300 lbs.), and in the exterior position reaches a maximum of 4000 kg. (8800 lbs.).

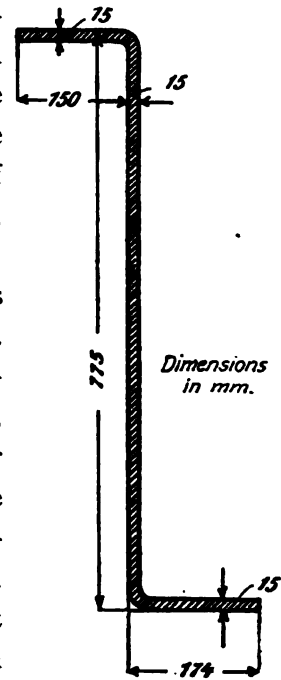


FIG. 9.

The arrangement of the braking mechanism, as shown on Plate IV, is essentially simpler than it was before. On account of the greater distance between the wheels, it was possible to place the brake-cylinders between and in the plane of the wheels. Each truck is equipped with two double and two single brake-cylinders, and each piston acts by means of levers upon only one wheel. This arrangement has almost done away with the heavy cross-rods and transmission levers; the accurate and uniform adjustment of all the brake-shoes has been facilitated, and the transmission of the braking power to the brake-shoes takes place with greatly reduced friction losses.

In order to secure a uniform braking pressure upon the wheels of one axle, the two cylinders are connected by a header, each pair being independent of the others, so that in case of defects in the piping or valves of any one pair of cylinders the working of the other cylinders is not affected. The air-brake can be actuated from each of the motorman's platforms for both trucks simultane-

ously, and besides, the motorman is able to regulate at will the pressure in the brake-cylinders by means of a valve installed on the platform. The car S was equipped, as an experiment, with a pressure-regulator designed by Privy Counsellor Wittfeld, which at decreasing speed allowed the air to escape from the brake-cylinders at such a rate that the retardation remained constant during the braking period. This pressure-regulator consists of a heavy pendulum swinging in the direction in which the car is running, and when the retardation of the car has attained a certain value, this pendulum swings out of the perpendicular position, and at this point a valve is opened by means of an electrical device, diminishing in this way the pressure in the brake-cylinders.

With an air-pressure in the brake-cylinders of from 6 to 8 atm. (88.3 to 117.78 lbs. p. sq. inch abs.), the pressure exercised on each of the 24 brake-shoes is 6000 to 8000 kg. (13,200 to 17,600 lbs.), respectively, and the total pressure amounts, therefore, to 145,000 or 192,000 kg., respectively (319,000 to 422,400 lbs.), equaling 154 or 205 per cent of the weight of the car. The ratio between the pressure upon the brake-piston and the pressure upon the two brake-shoes of a wheel actuated by this piston is 1 to 4; at the longest stroke of the piston of 100 mm. (3.93 inches) the brake-shoes have therefore a throw of 25 mm. (0.98 inch).

The hand-brakes are applied by means of a hand-wheel installed upon the platform and act only upon the two axles of the truck which are nearest to the platform, and upon the same brake-shoes which are connected to the double cylinders. On car A the middle axle and the front outside axle of the truck are braked by hand, as shown on Plate IV, whereas on car S the hand-brake acts upon the middle axle and the axle near to the middle of the car, as shown on Plate XVII of last year's report. The restriction of the hand-brakes to only two axles of the truck seems permissible, as even at the largest possible ratio of transmission on the levers, the power exerted by hand is not sufficient to reach the highest brake pressure upon four wheels. Supposing that at each hand-wheel of the brake a power of 40 kg. (88 lbs.) is applied, the pressure on each of the 16 brake-shoes is then about 3430 kg. (7546 lbs.), and the total pressure about 54,880 kg. (120,736 lbs.), equal to about 59% of the weight of the car. The ratio of transmission in this case is 1 to 686.

The simplification of the truck frames and of the brake arrangement made it possible to maintain for the new swivel trucks the same weight as for the old ones notwithstanding that the wheel distance was greater and the strength

of the truck was not diminished. Therefore there was no increase in the total weight of the high-speed cars.

As already mentioned in the first report concerning the tests in the fall of 1901, the motors of car A were hung on springs, and this arrangement, shown on Plate V, gave very satisfactory results even at the higher speeds. The motor case was hung from the supports *aa*, which rest upon the flat springs *bb*, the latter being placed upon the middle band of the flat springs *cc* of the truck. The motor frame carries a hollow shaft mounted upon the axle of the car, and this hollow shaft carries the armature of the motor. The motor is connected to the wheels of the car by means of an elastic coupling. Referring to Plate V,

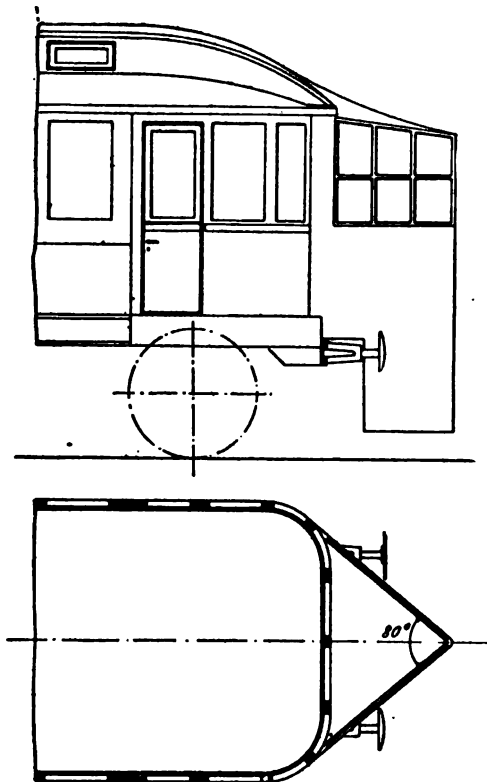


FIG. 10.

the springs *dd*, mounted stationary upon the hollow motor shaft, lie with their free ends toward the blocks *ee*, which are attached to the wheels. There is a play of 8 mm. (0.32 inch) between the hollow shaft of the motor and the car axle, so that jerks which occur at the wheels and the axle are not transmitted directly to the motor.

For car S, on which the motors had not as yet been suspended elastically, the arrangement shown on Plate VI was used in order to save the motors. The rotor is pressed upon the car axle and the motor frame rests upon the car axle and is held by bolts *dd*. The springs *aa* are mounted on the cross-trusses of the truck (Plate VI) and carry the supports *bb*. The motor frame is carried by projections *cc*, which rest upon the supports *cc* and is pressed to the axle from below by the springs *aa*. The tension of these springs can be calculated from the weight of the motor frame of 2450 kg. (5390 lbs.), the weight

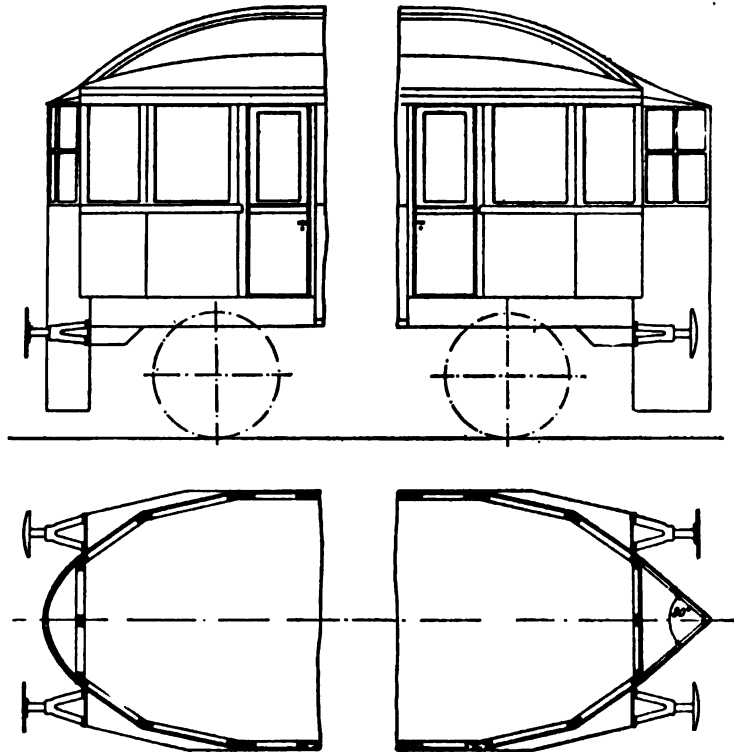


FIG. 11

of the supports *bb* of 250 kg. (550 lbs.), and an additional tension of 1300 kg. (2860 lbs.), corresponding to the play of the springs, giving a total of 4000 kg. (8800 lbs.) or 2000 kg. (4400 lbs.) for each spring. It was found during the tests that this arrangement took the load from the axle and diminished the shocks considerably.

In the former runs with car S the vibrations of the sides of the car body were so great that it was impossible to accurately read the measuring instruments fastened to them. This difficulty was overcome by replacing the two

light wooden partitions near the doors with two portals built of standard iron sections.

In order to study the effect of the form of the front of the car on the air resistance, both cars were equipped on the front end with noses, as shown in Figures 10 and 11, which reach down from the roof of the car to within 30 and 40 cm. (11.7 and 15.4 inches) respectively of the head of the rail and which can be easily attached or removed during the tests.

### 5. Measuring-instruments.

As the speed is of the greatest importance for all observations, the greatest care has to be taken in its exact measurement. The Morse apparatus with three writing-levers, as used for these measurements in the former tests, gave good results, and therefore the same apparatus, after having been carefully cleaned and readjusted, was employed in this year's tests. In order to obtain an absolutely sure contact, even at the highest number of revolutions of the wheels, the contact discs upon the middle axle and the sliding springs were improved by using a new construction, so that the vibration of the axles and the jumping of the sliding springs had no influence upon the regularity of the con-

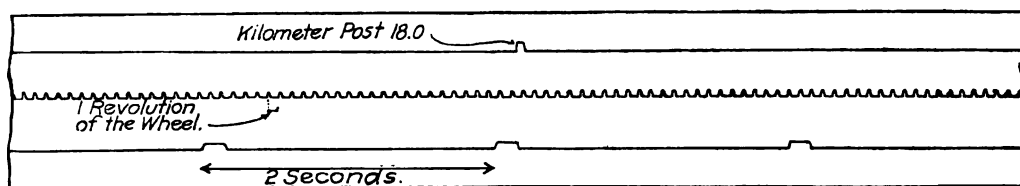


FIG. 12.

tact. With these improvements exact records up to 15 r. p. s., corresponding to a car speed of 210 km. (129.9 miles), could be made on the paper. Part of such a record is shown in Figure 12 for a speed of 185 km. p. hr. during run No. IV of November 19th. The line in the middle represents the revolutions of the wheel, the lower line the time; the contacts being made in this case at intervals of two seconds. The clockworks formerly used for this purpose, making a contact every ten seconds, did not work satisfactorily, and have been improved in the past year by several changes as to the motive power, the escape-device, and the elastic suspension. After these improvements were made, the clockworks were regulated for several months. The result was that the three clockworks installed in the two cars and at the distributing-pole were

running almost in synchronism, so that the difference in time after a three-hour test generally did not amount to more than one second; on the other hand, the time intervals from contact to contact did not differ more than  $1/100$  of a second. In the new construction the contact is improved by using platinum on the spring, which is actuated by a steel cam-wheel, shown in Figure 13. The cam-wheel is adjusted in such a manner that the contact is made at the moment the

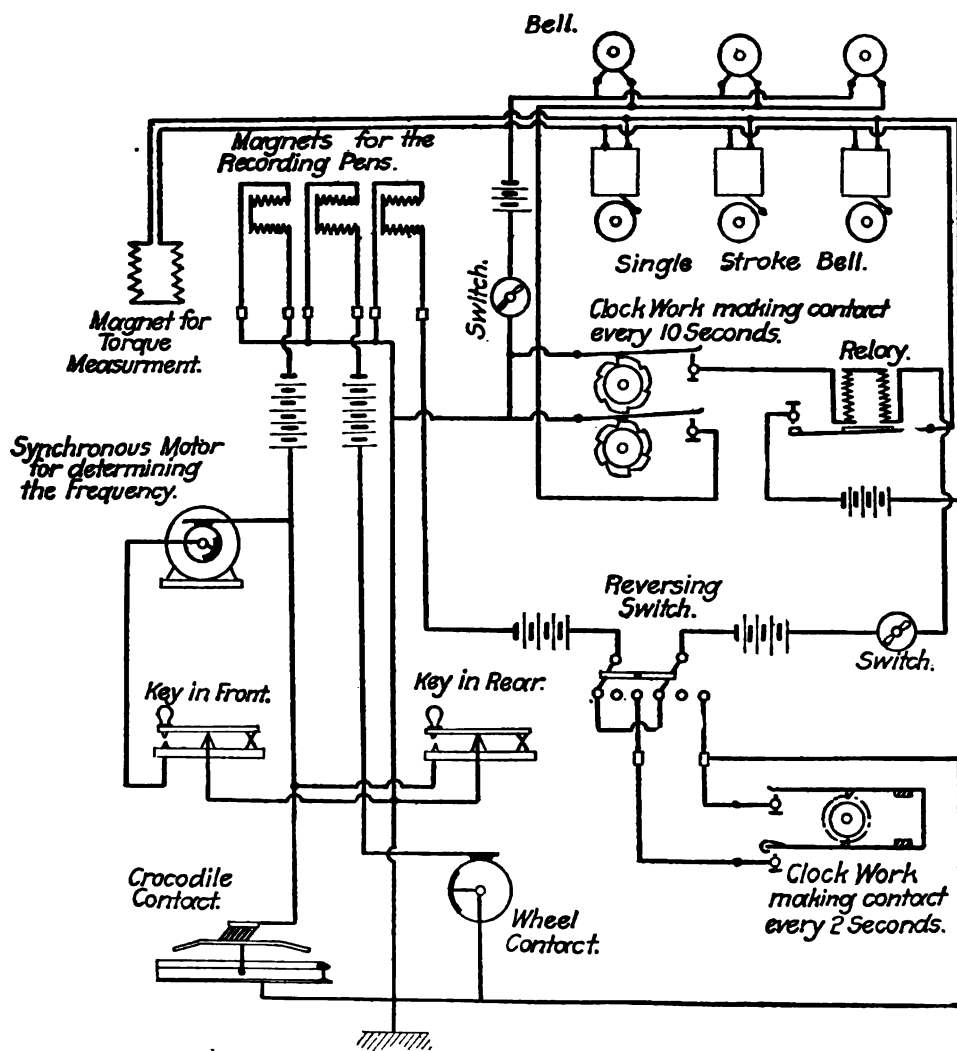


FIG. 13.

ratchet is in its middle position, as at this moment the speed of the ratchet-wheel is at its highest value, so that small irregularities in the clockworks do not materially affect the result. The contacts not only make records of the time upon

the slip of paper, but also give bell signals at intervals of ten seconds in different parts of the car, which enables the observers to read the instruments simultaneously. The clockwork at the distributing-pole was brought in synchronism with the watches in the car by telephonic communication every day before the tests started, and after the tests were finished the difference in the time was determined in the same manner. This difference was generally so small as to be negligible when plotting the time-speed curves.

In order to determine the speed at shorter intervals in breaking and coasting tests, another clockwork making contact every two seconds was used, which could be connected at will to either one of the cars. The severest conditions as to the accuracy of this watch were predetermined, and the watch factory of Siemens & Halske succeeded in reaching an accuracy in the time contacts of about  $1/500$  of a second. In order to damp the vibrations at the start of

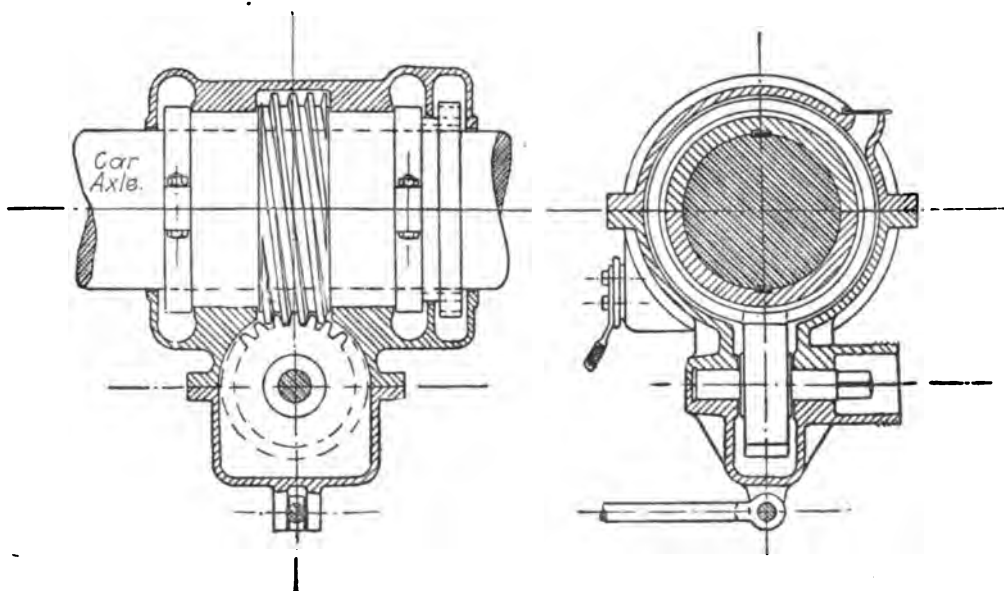


FIG. 14.

the car, all the clockworks in the cars were suspended by means of rubber balls and spiral springs.

In the former tests the time of passing the kilometer-posts was recorded by means of the Morse key connected with the third magnet in order to give a check on the distance. It was very difficult to do this with accuracy at very high speeds, and in order to accomplish it, so-called crocodile contacts were placed at intervals of one kilometer (0.62 mile) along the road, and the cars were equipped with



metal brushes. The brushes in making contacts when the car was passing the kilometer-posts closed the circuit of the third magnet and, by means of the Morse key, made a record upon a slip of paper. These kilometer signs, in connection with the records of time, give an accurate measurement of the speed, and together with the revolution records serve as a means of calculating with precision the slip upon the rail. The keys were also used to record the shutting off of the power, stopping of the car, etc.

The rail contacts used in the first year were not employed again, as the arrangement described above proved to be better for the measurement of speed and never failed to work satisfactorily during the whole test period.

In addition to these three-contact recorders, each car was equipped with a speed recorder of Haushalter and Grossmann, respectively, which also made records of the speed, yet not with the same accuracy as the Morse apparatus. The driving arrangement of the Haushalter apparatus, as shown in Figure 14, gave satisfactory results in car S.

In order that the motorman might observe the acceleration and the retardation, a glass tube was mounted vertically on each platform of car S and a connection was made between the tubes by means of a lead pipe run along the outside of the car. The position of the liquid in the communicating tubes indicated the acceleration or retardation at any moment. This device, designed by Kapp, can, on account of its simplicity, be employed in all cases where a certain value of acceleration or retardation will not be exceeded.

The measurement of the air pressure on the oblique sides of the car nose by means of the water-gauges, as employed heretofore, was influenced greatly by the wind and depended upon its direction. An attempt was made, therefore, to determine the air pressure on the oblique sides of the nose of the car S by means of a box gauge specially built for this purpose. On this gauge the air pressure acts directly upon a slightly corrugated metal diaphragm 15 cm. (5.85 inches) in diameter. The empty space behind the diaphragm is connected by a non-elastic thick lead pipe to a glass tube, provided with a scale, in the interior of the car. The gauge and the lead pipe are completely filled with water, but the glass tube is filled only up to the zero-point on the scale. A pet-cock for the air is mounted on the diaphragm plate. An inlet cock and an outlet cock placed on the glass tube serve for the purpose of bringing the liquid to the zero-point before the test starts. The results obtained with this apparatus have not been satisfactory up to the present time as the acceleration

or retardation of the car exercised a great influence upon the position of the water-level in the tubes, and in addition to this, small differences of temperature caused a change of level of the water in the glass tube during the run. Yet it is hoped that the apparatus can be improved in this respect, and that it can be made suitable for exact measurements of the air pressure.

The arrangement for measuring the torque of the motors, described on page 22 of the former report, was not used again, as it would have been necessary to renew most of the parts of this mechanism in mounting it on the new trucks. Besides, the construction of a hydraulic torque measuring apparatus was taken into consideration. The device consists of a cylinder filled with oil fitted with a tight piston. The piston is connected by a connecting-rod to the frame of

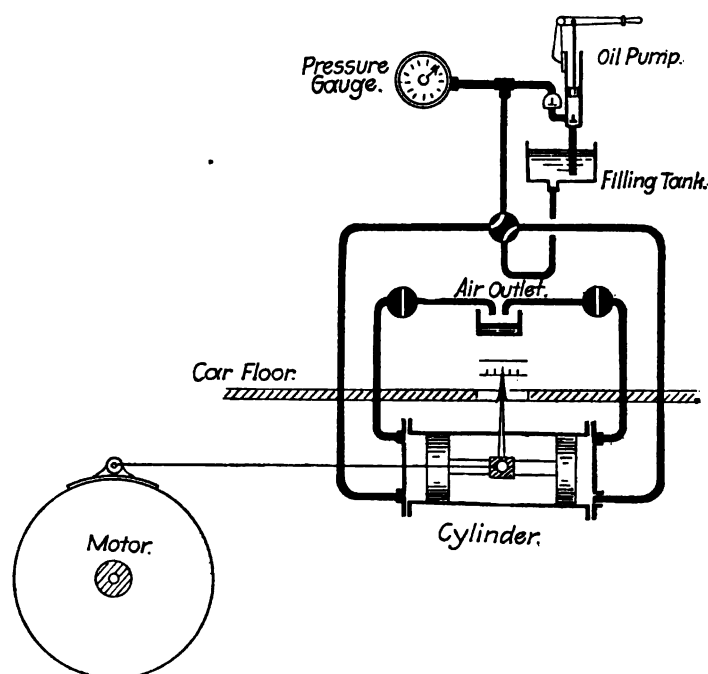


FIG. 15.

the motor, which transmits the reaction to the piston, producing a pressure in the oil. The pressure of the oil can be read on a gauge which is constructed as a recording instrument indicating the pressure directly upon a strip of paper, turned by a clockwork. The apparatus is also equipped with an outlet and filling device in connection with the oil-pump. In order to avoid the swinging of the pointer, the gauge is mounted on springs. Vibrating variations of the pressure can be dampened by a throttle-valve without influencing the readings

of the gauge. This arrangement is shown diagrammatically in Figure 15, while on Plate VII we see the cylinder with piston and piston-rod. As the installation of this device caused greater difficulties on car A than on car S, it was only used on the latter and only on one of the motors in order to test its practicability. The torque of the other motors can be found by comparing the ammeter readings on the primary side of the motors. The apparatus worked satisfactorily, but its application is restricted, its use makes it necessary to detach the motor frame from the supporting springs, as the latter influence the pressure on the piston at the least turning of the motor frame, making the measurement incorrect. In consequence of the motor frame being dismounted from the springs, the distribution of load on the axles is changed. This did not seem to be admissible at the higher speeds. The friction in the motor bearings is not included in the measured torque and can be calculated approximately; besides, the value of the friction losses is small compared with the power delivered to the axles.

No special changes in the method of measuring the current consumption were made.

In order to determine the frequency, a little three-phase motor was installed in car S which was running in synchronism with the alternators at the power-station, and the axle of which was equipped with a contact disc. This contact disc was connected to one of the Morse keys. With this arrangement an exact record of the number of revolutions of the motor and of the frequency was made. Such a device was absolutely necessary, as the method employed heretofore for the determination of the frequency by counting the number of revolutions of the alternators in the power-station has given very unsatisfactory results, and the frequency is also of great importance in determining the speed of the car. At the distributing-pole the insulation of the instruments was improved to such an extent that it was made possible to take reliable readings even in bad weather.

In order to observe the individual movements of the swivel truck a pointer was fastened at the end and at the middle of the truck and a hole was cut in the floor of the car, through which this pointer protruded. Each pointer was connected to a writing-pen by means of a lever arrangement and made a record of the lateral movement of the truck, in relation to the car body, upon a drum driven by clockwork.

### 6. Signal Apparatus.

In order to make the signals visible directly from the car a long distance before they were reached, crocodile contacts were installed about 2000 m. (6560 feet) before the clear-track signals at the Mahlow and Ransgdorf stations, and were connected with the stations by means of overhead wires. These contacts, consisting of angle iron, are 4 m. (13.12 feet) long and are fastened to the ties and insulated from them. A contact brush mounted on one of the journal boxes of car S made contact with the above device when the car passed. The contact brush is connected to an electromagnet installed on the platform, the other end of the magnet winding being grounded through the truck. If now at one of the stations one of the poles of a battery is connected to the crocodile contact and the other pole to the rail, the circuit of the magnet is closed by the contact brush when the car passes. The closing of the circuit releases a spring, causing a red disc to appear. The same apparatus can be connected without difficulty to an electric bell installed in the car, which rings when the signal stands at danger. In order to test out this arrangement, these crocodile contacts have always been connected to the battery during the test runs, so that the signal had to appear at each passage of the car. This device did not fail to work even at the highest speeds, but it is doubtful if it would work with absolute safety when the crocodile contacts are covered with snow and ice. Taking these conditions into consideration it seems advisable to substitute induction for the sliding contacts and in this way produce the current for operating the signal device in the car. Tests with such apparatus were made by the Siemens & Halske Aktiengesellschaft.

Finally, it may be mentioned that the Administration of the Military Railroad has replaced the low signal masts on the road by masts 14 m. (45.92 feet) high, so that the overhead structure would not obscure the signals.

The signal-houses of the test road were equipped with telephones by the Administration, which proved to be of great advantage for the tests. In this way it was possible to have telephonic communication at any moment with each one of the stations, the car-sheds, or with the distributing-pole.

## II. RESULTS OF THE TEST RUNS.

### 1. Breaking and Starting Period.

In starting the car, it had to be considered that the generators in the power-station carrying a large lighting load should not be overloaded by great current fluctuations. It was, therefore, not possible to increase the acceleration at the start to such a value as would have been obtainable with the electrical equipment on the car. On the other hand, the value of the acceleration depended upon the location of the curves, which had a radius of 2000 m. (6560 feet), and which, according to the Regulations of the Supervising Government Board, could not be passed at a higher speed than 160 km. (100 miles). For these reasons the highest average acceleration for starting at Marienfelde was 0.2 meter-sec. p. sec. (0.44 mi. p. hr. p. sec.), and for starting at Zossen 0.15 meter-sec. p. sec. (0.335 mi. p. hr. p. sec.). For an experimental purpose the acceleration was increased in some of the test runs to 0.35 meter-sec. p. sec. (0.78 mi. p. hr. p. sec.), as seen in the curve sheets. When passing the curves in these tests the current was off and the brakes were in operation. The average acceleration at the start for 200 km. (124 miles) speed was about 0.15 to 0.18 meter-sec. p. sec. (0.332 to 0.402 mi. p. hr. p. sec.), and the starting distance 9000 to 10,000 meters (29,520 to 32,800 feet). For commercial high-speed services, where the trains have to run great distances without stopping, such values for the acceleration would be entirely sufficient. In this case it was not the purpose to make the starting period, which was only a small portion of the whole run, especially short; but for a high-speed service with many stops, an especially high acceleration during the start would be of the greatest importance. There is no doubt that in employing generators specially built for this purpose, accelerations of at least 0.75 meter-sec. p. sec. (1.678 mi. p. hr. p. sec.) could be reached. As to the braking, far more favorable results have been obtained on account of the simplification of the brake lever arrangement. These results are given in the following table:

| Number of the Run. | Kilometer-post at which Brake was Applied. | Speed at the Beginning of the Braking Period. Miles per Hour. | Braking Distance. Feet. | Braking Period. Seconds. | Air Pressure.                  |                                    | Average Retardation, $p = \frac{v}{t}$ . Miles per Hour per Sec. | Retarding Force in Per Cent of the Weight of the Car. |
|--------------------|--------------------------------------------|---------------------------------------------------------------|-------------------------|--------------------------|--------------------------------|------------------------------------|------------------------------------------------------------------|-------------------------------------------------------|
|                    |                                            |                                                               |                         |                          | In the Pipes. Lbs. per Sq. In. | In the Cylinders. Lbs. per Sq. In. |                                                                  |                                                       |
| CAR A.             |                                            |                                                               |                         |                          |                                |                                    |                                                                  |                                                       |
| I                  | 15.0-16.29                                 | 96.8                                                          | 4235                    | 55                       | 92.62                          | 66.02                              | 1.98                                                             | 8.1                                                   |
| II*                | 24.99-26.3                                 | 100.3                                                         | 4299                    | 50                       | 95.58                          | 73.50                              | 1.68                                                             | 7.7                                                   |
| III                | 15.93-14.52                                | 103.4                                                         | 4634                    | 61                       | 105.65                         | 79.45                              | 1.705                                                            | 7.8                                                   |
| IV                 | 19.46-20.9                                 | 109.8                                                         | 4732                    | 58                       | 136.60                         | 95.58                              | 1.902                                                            | 8.7                                                   |
| CAR S.†            |                                            |                                                               |                         |                          |                                |                                    |                                                                  |                                                       |
| V                  | 15.09-16.36                                | 96.3                                                          | 4168                    | 55                       | 92.62                          | 61.79                              | 1.745                                                            | 8.0                                                   |
| VI                 | 25.1-26.46                                 | 99.4                                                          | 4465                    | 59                       | 94.09                          | 63.20                              | 1.678                                                            | 7.7                                                   |
| VII                | 16.0-14.7                                  | 105.5                                                         | 4266                    | 53                       | 132.10                         | 85.18                              | 1.99                                                             | 9.1                                                   |
| VIII               | 19.38-20.75                                | 111.7                                                         | 4500                    | 54                       | 132.10                         | 88.21                              | 2.085                                                            | 9.5                                                   |

\* Test II.—At a speed of 27 km. (16.86 miles) the brakes were released.

† The device for reducing the braking pressure with decreasing speed was used.

The eight brake tests, as represented graphically on Plates IX, IXa, X and Xa, show that the average retardation for the whole braking distance at an initial speed of 160 to 180 km. (100 to 111.6 miles) is 0.8 to 0.9 meter-sec. p. sec. (1.79 to 2.01 mi. p. hr. p. sec.). The braking distance at these initial speeds was 1300 and 1400 m. (4264 to 4592 feet). The curves show a similar course as in the previous tests. At the beginning, when the brakes are set, the speed decreases rapidly, then more gradually, corresponding to the friction coefficient, which decreases with the time; at the end of the braking period the speed decreases again more rapidly, due to the increase of the coefficient of friction. The retardation curves on these plates show still more clearly the braking effect; they also show the effect of the apparatus for the reduction of the braking pressure with decreasing speed installed on car S and described on page 14.

In comparing Plates IX, IXa, X and Xa, which show the brake tests of each one of the cars, we find that the retardation of car S decreases more rapidly at the beginning than that of car A, on account of the above apparatus being put in action as soon as the retardation attained the limit provided for. A different limit was selected for each test. On car S the air escapes from the cylinders a few seconds after the brakes have been set, diminishing the pressure in the

brake-cylinders from one-quarter to one-half atm. (3.67 to 7.35 lbs. p. sq. inch abs.), corresponding to a total braking pressure of 6000 to 12,000 kg. (13,700 to 26,400 lbs.). On car A, where the reducing of the pressure had to be done by hand by means of a valve mounted on the platform, the air pressure in the brake-cylinders was not reduced at the beginning of the braking period. After the speed had decreased to about 80 or 70 km. (49.6 to 43.4 miles) the air was then let out by the hand-valve in order to avoid skidding of the wheels at a further decrease of the speed. The apparatus on car S was only put in action when the retardation exceeded the predetermined value. As the curves show, the main diminution of the pressure generally took place at a speed of not more than 30 km. (18.6 miles); i.e., far much later than in the case of car A. These circumstances show that the brake results on car S are more favorable than those on car A, notwithstanding that in the latter case the unfavorable effect of the diminution of the brake pressure at the beginning of the braking period was avoided. If it is found that on car S, at the end of the braking period, the retardation rises to a higher value than the apparatus should allow, the reason is that the friction coefficient, and with this the retardation at low speed, increases very rapidly, while the diminution of the braking pressure does not follow at the same rate.

The curves also teach us how the braking pressure has to be regulated in order to obtain the most favorable braking effect. The most favorable results are obtained if the retardation is kept constantly at as high a value as the service will allow. For this purpose it would be necessary to increase the braking pressure a few seconds after the brakes were put in operation, which effect could be obtained by a similar device, as described above. This device could be put in operation as soon as the retardation falls under the predetermined value and should increase the pressure in the brake-cylinders. If, for instance, a uniform retardation of one meter-sec. p. sec. (2.235 mi. p. hr. p. sec.) could be obtained, the braking distance at an initial speed of 180 km. (111.6 miles) on a level stretch of track would be 1250 m. (4100 feet); that is, 120 m. (393.6 feet) shorter than the braking distance obtained in test No. VIII. If it should be necessary to shorten the braking distance still more, a greater retardation would have to be employed, which, in case of danger, could be increased without objection to 1.5 meter-sec. p. sec. (3.35 mi. p. hr. p. sec.), under which circumstances the braking distance would be reduced to 830 m. (2725 feet) at an initial speed of 180 km. (111.6 miles) p. hr. This retardation can be obtained by the Westing-

| Average Speed in Miles per Hour. | No. of Test.                                   | Seconds after Applying the Brakes.             | Retardation Miles per Hour per Second.                               | Braking Pressure, <i>D</i> . Lbs.                                            | Friction Coefficient, <i>f</i> .                                     | Average Friction Coefficient. | Remarks.                                                                                                                  |
|----------------------------------|------------------------------------------------|------------------------------------------------|----------------------------------------------------------------------|------------------------------------------------------------------------------|----------------------------------------------------------------------|-------------------------------|---------------------------------------------------------------------------------------------------------------------------|
| 109                              | VIII                                           | 1                                              | 2.46                                                                 | 299500                                                                       | 0.069                                                                |                               |                                                                                                                           |
| 105.2                            | IV<br>VIII                                     | 2<br>2                                         | 2.39<br>2.46                                                         | 325900<br>299500                                                             | 0.062<br>0.069                                                       | } 0.066                       |                                                                                                                           |
| 99.2                             | II<br>III<br>IV<br>VII<br>VIII                 | 0.5<br>2<br>4.5<br>3<br>5                      | 1.718<br>2.085<br>2.35<br>2.322<br>2.554                             | 250800<br>270300<br>325900<br>290300<br>299500                               | 0.061<br>0.064<br>0.062<br>0.068<br>0.074                            | } 0.066                       |                                                                                                                           |
| 92.9                             | I<br>II<br>III<br>IV<br>V<br>VI<br>VII<br>VIII | 2<br>4<br>5.5<br>7<br>1.5<br>3<br>5.5<br>7.5   | 1.785<br>1.832<br>1.718<br>1.97<br>1.812<br>2.125<br>2.016<br>2.058  | 226700<br>250800<br>270300<br>325600<br>211200<br>215700<br>290300<br>286100 | 0.065<br>0.061<br>0.052<br>0.051<br>0.076<br>0.086<br>0.059<br>0.061 | } 0.064                       |                                                                                                                           |
| 80.3                             | I<br>II<br>III<br>IV<br>V<br>VI<br>VII<br>VIII | 10<br>11<br>13<br>14<br>9<br>10<br>12.5<br>14  | 1.567<br>1.615<br>1.765<br>1.785<br>1.588<br>1.588<br>1.703<br>1.846 | 226700<br>250800<br>270300<br>325900<br>200000<br>202400<br>270300<br>275000 | 0.058<br>0.055<br>0.053<br>0.047<br>0.067<br>0.066<br>0.054<br>0.060 | } 0.058                       |                                                                                                                           |
| 62.0                             | I<br>II<br>III<br>IV<br>V<br>VI<br>VII<br>VIII | 22<br>23<br>24<br>25<br>22<br>23<br>23<br>24   | 1.545<br>1.656<br>1.656<br>1.745<br>1.568<br>1.458<br>1.812<br>1.880 | 226700<br>250800<br>270300<br>325900<br>187200<br>191600<br>242000<br>264000 | 0.061<br>0.059<br>0.051<br>0.048<br>0.075<br>0.067<br>0.064<br>0.065 | } 0.061                       | Up grade 1:200<br><br>Up grade 1:200 |
| 31.0                             | I<br>II<br>III<br>IV<br>V<br>VI<br>VII<br>VIII | 41<br>42<br>43<br>43.5<br>40<br>43<br>40<br>41 | 1.812<br>1.704<br>1.586<br>1.785<br>1.812<br>1.614<br>1.950<br>1.950 | 202400<br>202400<br>202400<br>250800<br>182500<br>187200<br>220000<br>220000 | 0.086<br>0.080<br>0.075<br>0.078<br>0.095<br>0.082<br>0.085<br>0.089 | } 0.084                       | Down grade 1:200<br><br>Down grade 1:200                                                                                  |



| Average Speed in Miles per Hour. | No. of Test. | Seconds after Applying the Brakes. | Retardation Miles per Hour per Second. | Braking Pressure, D. Lbs. | Friction Coefficient, $f$ . | Average Friction Coefficient. | Remarks.         |
|----------------------------------|--------------|------------------------------------|----------------------------------------|---------------------------|-----------------------------|-------------------------------|------------------|
| 15.5                             | I            | 49                                 | 2.235                                  | 189000                    | 0.12                        | 0.11                          | Down grade 1:200 |
|                                  | III          | 52                                 | 1.970                                  | 176000                    | 0.11                        |                               |                  |
|                                  | IV           | 51                                 | 2.017                                  | 198000                    | 0.104                       |                               | Down grade 1:200 |
|                                  | V            | 48                                 | 2.215                                  | 180500                    | 0.13                        |                               | Down grade 1:200 |
|                                  | VI           | 52                                 | 1.900                                  | 185000                    | 0.096                       |                               | Up grade 1:320   |
|                                  | VII          | 47                                 | 2.322                                  | 269000                    | 0.11                        |                               |                  |
|                                  | VIII         | 48                                 | 2.440                                  | 209000                    | 0.12                        |                               | Down grade 1:200 |
|                                  |              |                                    |                                        |                           |                             |                               |                  |
| 6.2                              | I            | 53                                 | 2.75                                   | 176000                    | 0.16                        | 0.13                          | Down grade 1:200 |
|                                  | III          | 57                                 | 1.568                                  | 151900                    | 0.10                        |                               |                  |
|                                  | IV           | 56                                 | 2.215                                  | 176000                    | 0.13                        |                               | Down grade 1:200 |
|                                  | V            | 52                                 | 2.370                                  | 178200                    | 0.14                        |                               | Down grade 1:200 |
|                                  | VI           | 56.5                               | 2.322                                  | 182700                    | 0.12                        |                               | Up grade 1:320   |
|                                  | VII          | 51                                 | 2.575                                  | 202400                    | 0.13                        |                               |                  |
|                                  | VIII         | 51.5                               | 2.75                                   | 202400                    | 0.14                        |                               | Down grade 1:200 |
|                                  |              |                                    |                                        |                           |                             |                               |                  |

house high-pressure brake, as is seen from the brake tests which were made in July and August of 1901 on the Northeastern Railroad of England with a train consisting of a locomotive, a baggage-car, and ten passenger-cars. At a pressure of 8 atm. (117.6 lbs. p. sq. inch) in the pipes and at a speed of 90 km. (55.8 miles) p. hr., the train was brought to a stop on a down grade of 1:330 within a distance of 260 m. (854.9 feet), corresponding to an average retardation of 1.47 meter-sec. p. sec. (3.288 mi. p. hr. p. sec.). This is probably the limit of the braking effect which can be allowed with a brake applied to the wheel.

According to the same method as described in the report of last year, it was also intended to calculate from this year's braking results the friction coefficient for different speeds. From the above tables it can be seen how the braking coefficient decreases at the beginning of the braking period in proportion to the time, but then increases rapidly with the decreasing speed.

For these calculations 5% is taken off of the values of the air pressures, as given by the readings, as the amount used in overcoming the friction of the brake-levers. This calculation is certainly not absolutely exact, and some of the values seem to indicate that the braking pressure is less in reality; yet this table gives a very good comparison of the calculated values.

For future tests it is to be recommended that the air pressure in the brake-cylinders be registered by a recording gauge, in order to find the friction coefficient with greater accuracy.

## 2. Air and Train Resistance.

The tests of last year gave an excellent opportunity for measuring the air resistance at high speeds. The results of a great number of measurements, which, as in former years, were obtained by U-shaped tubes, check up well with one another. On Plate XI the values as observed during three runs from Marienfelde to Zossen and during two runs from Zossen to Marienfelde are given. The measurements were made on three different days, and in recording the values the direction of the wind and the strength of the wind were taken into consideration, as already described in the preceding report. The curve for the air pressure corresponds to the formula  $P = 0.0052 V^2$ , wherein  $P$  is the air pressure for one square meter (10.76 sq. ft.) of plane surface perpendicular to the direction in which the car is running,  $V$  is the speed in kilometers p. hr. While it seems that the curve gives at lower speeds somewhat higher values than the values found in reality, and *vice versa* at higher speeds, it checks up well as a whole with the readings. If still a nearer approximation of the values is desired, it would be necessary to decrease the coefficient 0.0052 for speeds up to 100 kilometers (62 miles) and increase it for speeds above 100 (62) or to change the exponent for  $V$ . In considering the very slight inaccuracy of the given formula and its great simplicity, it seems to be justifiable to retain it in its present form and employ it regularly in railroad practice. For other shaped bodies, especially for single disc, other values for the air resistance are obtained, as can be seen from the tests of von Loessl.

Colonel von Scheve recently informed us that in the Artillery Corps a formula given by Newton is used for the calculation of the air resistance of projectiles.

The formula reads:  $P = \frac{A}{2g} V^2$ . In this formula  $A$  indicates the weight of one cubic meter (35.31 cu. ft.) air and  $V$  the speed. If we put in for  $A$  the average value of 1.293 and give  $V$  in km. p. hr., we obtain  $P = 0.0051 V^2$ ; that is to say, nearly exactly the same value as it has been found in the tests.

In the tests the air pressure prevailing on the oblique sides of the noses was also measured. On Plates XII and XIII the outlines of the car are shown and also the places where the measuring tubes were mounted. The speed and the measured air pressure at the different points on the oblique sides are shown by the curves. These measurements show that the pressure against the oblique sides is not uniform, and decreases with the distance from the front edge, where it is strongest; towards the rear and at the end of the oblique sides the current

of air is so strong that a suction effect is produced. The measurements on car S show a very marked suction effect on pipe IV, while at the same relative place on car A, generally there was but a very small pressure. This difference is due to the different wind directions on the days of the respective runs, and it is probable that both tubes IV of the two cars would indicate a suction effect if there was no wind, which would probably be less than the suction effect measured on car S, as in this case the wind was in such a direction as to increase the suction effect of the air. The air pressure upon the sides of the cars is, as has already been stated, comparatively small, and depends upon the direction and the strength of the prevailing wind, while at the rear end of the car no pressure or great suction effect is noticeable. Furthermore, the value of the air

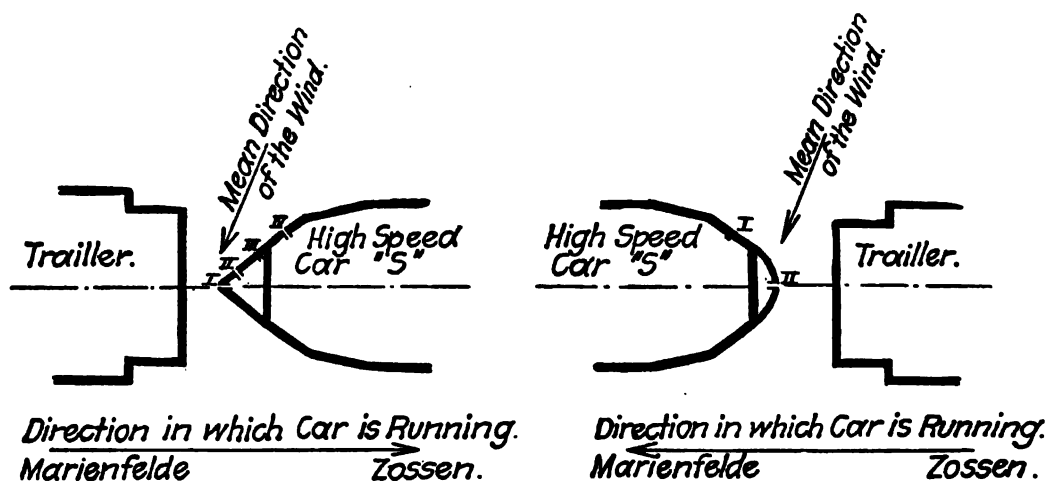


FIG. 16.

pressure between the motor-car and the sleeping-car as trailer was observed during the run. On account of the lack of time these measurements could be conducted only on car S and by means of the tubes mounted on the oblique front sides. In these tests tubes II, III, and IV in Figure 16 show a low pressure; at a speed of 160 to 170 km. (100 to 105.4 miles) a pressure of 3 kg. p. sq. m. (0.6132 lb. p. sq. ft. abs.) was registered by tube II, about 6 kg. (1.22 lbs. p. sq. ft. abs.) by tube III, and about 8 kg. (1.63 lbs. p. sq. ft. abs.) by tube IV. At the opening of tube I neither pressure nor suction was observed. The run in the opposite direction was made with the rounded-off end of car S (see Figure 16) turned towards the trailer. In tube II, which was mounted in about the middle of the oblique surface, a suction effect of 6 kg. p. sq. m. (1.22 lbs. p. sq. ft. abs.) was shown, whereas the tube I showed no effect. That in one direc-

tion a pressure effect and in the other a suction effect was observed can only be explained by the direction of the wind, which is clearly indicated in the drawings. From these measurements it is concluded that the air resistance on the trailers is of small importance compared with the air resistance of the motor-car. The total resistance of the car was determined in the same way as in the year 1902; i.e., by a long series of coasting runs, which this time were begun with a far higher initial speed. For these tests the improvement on the speed indicators, as mentioned on pages 17 and 19, proved to be very useful. The measurement of the speed was greatly facilitated by the use of the new clockwork contact device, which made a record on the drum at intervals of two seconds. The rail contacts also made it possible to determine for each test run the ratio between the revolutions of the wheels and the actual distance run through.

Finally, the greatest accuracy was attained in working up the records on the strips of paper by using a transversal glass rule with an etched scale especially made for this purpose, together with a very strong magnifying-glass. The speed curves obtained in this manner had to be reduced to the horizontal in order to eliminate down grades. This was done in the following manner: In Figure 17 let  $abcd$  be the speed curve as found by the records, the track being

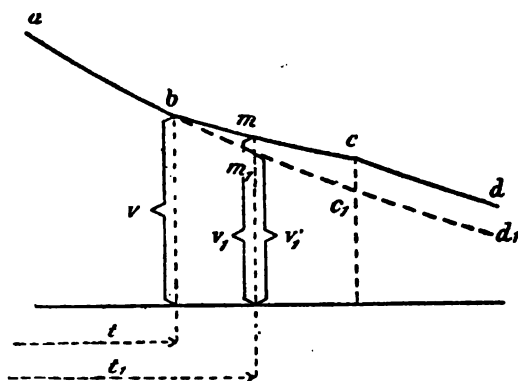


FIG. 17.

horizontal between  $a$  and  $b$ , and between  $c$  and  $d$ , and having a down grade of  $\frac{h}{l}$  between  $b$  and  $c$ . If  $Q$  is the weight of the car, then it is acted upon by the force  $\frac{Qh}{l}$ , which would produce an acceleration  $p$  if the car was on a horizontal stretch. It is therefore  $\frac{Qh}{l} = p \frac{Qk}{g}$ , and wherein  $k$  is a factor which takes into consideration the moving masses. From this equation we find  $\frac{hg}{lk} = p = \frac{V_1 - V_1'}{t_1 - t}$ .

From this we can calculate  $V_1 - V_1' = mm_1$ , and construct the line  $bm, c, d$ , which represents the speed curve, if the track were horizontal between  $b$  and  $c$ . From these corrected speed curves the retardation and the retarding force were found; i.e., the total resistance of the car at different speeds. On Plates XIV, XIVa and XV these calculated values are plotted in, for car A without noses and for car S with noses. By connecting the points found in this manner we get the curves for the total resistance of the car from speeds of 50 to 200 km. (31 to 124 miles). On Plate XV these curves are drawn side by side in order to make comparison more easy. These resistance curves check up very well with those found last year for speeds up to 120 km. (74.4 miles) p. hr.; for higher speeds the resistance curves rise somewhat faster than was expected. The pointed noses diminish the air resistance very considerably—for instance, at a speed of 200 km. (124 miles) it is reduced about 8%. If from the start, in constructing the car, the most favorable form for overcoming the air resistance is used, the air resistance can be still further diminished. These cars were not designed to use with noses, so it was not possible to build the latter in such a way as to cover all projecting parts and to give the whole car the most favorable form for overcoming the air resistance.

For the coasting tests the sliding bows were withdrawn from the trolley, and the total resistance of the car during the run with the sliding bows on the trolley-line is larger in correspondence to the larger surface of resistance. The equivalent area of the six sliding bows of a car when on the wire is  $1\frac{1}{2}$  sq. m. (16.20 sq. ft.) larger than when off. It is therefore of the greatest importance to construct and install the sliding bows in such a way that they offer the least resistance. The exact separation of the air resistance, car friction, and the rail friction is not possible, from measurements available at the present time, as the exact value of the equivalent area of the car is not yet known. They could be calculated, if coasting tests in each direction could be made on a day when a constant strong wind was blowing, from the difference between the resistance in one direction and that in the other. The results obtained from the tests do not give sufficient data for these calculations. By comparing the geometrical calculation of the surface with the air resistance measured during the test runs, we get the value of the equivalent area of the car without noses as about 9.6 sq. m. (103.2 sq. ft.), and with noses about 8.8 sq. m. (94.80 sq. ft.). Based upon these values we find on Plate XVa the curves for the total resistance as well as those for the air resistance, the total friction losses, and power consumption.

### 3. Power Consumption.

The improved insulation of the instruments installed at the distributing-pole permitted the measurement of the power consumption, of the current, and of the voltage during the whole test period, and these measurements checked up very well with those made on the car. On Plates XVI to XXXVI a number of them are shown graphically. The records of speed, current, voltage, and power consumption during the run were plotted as curves and calculated with a planimeter. The values found in this way are compiled in the foregoing table.

Concerning the starting, it may be mentioned again that the electrical equipment of the cars would have allowed a far much greater acceleration, but it was necessary to keep the latter within the limits indicated by the curves on account of the power-station which furnished the current and on account of the curves. The acceleration at the start amounted to an average of only 0.15 to 0.18 meter-sec. p. sec. (0.332 to 0.402 mi. p. hr. per sec.) and the power consumption during the starting period exceeds that during the continuous run at a uniform speed by only 400 to 600 metric H.P. (394.5 to 591 H.P.). In order to be able to compare the values of the power consumption found for continuous runs they were reduced to the level track with a wind velocity of 0. The influence of the wind was allowed for in the following manner: An equivalent area of 9 sq. m. (96.84 sq. ft.) was assumed for each car, and then the difference of the resistance of such a surface under the particular speed was calculated, first, in the prevailing wind, and, second, in calm air. Besides, the efficiency of the electrical equipment of the cars was taken into account. The efficiency was calculated by comparing the electrical readings reduced to a horizontal stretch and calm air with the resistance of the car as found in the coasting tests, and was found to be 0.83, taking into consideration that the sliding bows were on the wires during the electric measurements and off during the coasting tests. The values thus obtained are compiled in the row preceding the last under H.P., and as a rule check up very well; where they do not, it may be that these discrepancies were caused by little irregularities in the recording instruments or by other things which could not be taken into account in working up the data. For instance, on one of the test days for some reason the speed was kept lower than it should be for that frequency, and it was necessary to have the starting resistance partially inserted during the run. A part of the power was lost in the resistance, and the actual power consumption of the motors was therefore

## BERLIN-ZOSSEN ELECTRIC RAILWAY TESTS.

RUNNING PERIOD—TABLE OF THE ELECTRICAL AND MECHANICAL  
MEAN VALUES.

| Date. | Run. | Average<br>Speed. | Electrical Measurements. |                               |       |      |                  |       |      |      |      |                      | Power at the<br>Drive Wheels<br>Reduced to<br>Calm Air and<br>Level Track,<br>Assuming an<br>Efficiency of .83. |  |
|-------|------|-------------------|--------------------------|-------------------------------|-------|------|------------------|-------|------|------|------|----------------------|-----------------------------------------------------------------------------------------------------------------|--|
|       |      |                   | Frequency.               | At the Distributing-<br>pole. |       |      | At the Trolleys. |       |      |      |      | In One<br>Direction. | Mean<br>Taken<br>from<br>Both<br>Directions.                                                                    |  |
|       |      |                   |                          | Amp.                          | Volt. | K.W. | Amp.             | Volt. | K.W. | P.F. | H.P. |                      |                                                                                                                 |  |
| 1903. | No.  | Miles<br>p. Hr.   | P. Sec.                  | Amp.                          | Volt. | K.W. | Amp.             | Volt. | K.W. | P.F. | H.P. | H.P.                 | H.P.                                                                                                            |  |

## CAR A—WEIGHT 206,500 LBS.

|       |     |        |    |     |       |      |       |       |      |       |      |      |        |
|-------|-----|--------|----|-----|-------|------|-------|-------|------|-------|------|------|--------|
| 10/22 | III | 106.9* | 40 | 100 | 9855  | 1335 | 100   | 9360  | 1285 | 0.795 | 1716 | 1368 |        |
| 10/24 | IV  | 110.0* | 40 | 97  | 10490 | 1320 | 96    | 10035 | 1045 | 0.63  | 1398 | 1150 |        |
| 11/14 | I   | 100.9* | 36 | 85  | 9640  | 1035 | 84    | 9180  | 955  | 0.715 | 1298 | 1096 | } 1056 |
| 11/14 | II  | 101.2* | 36 | 81  | 9640  | 980  | 80    | 9110  | 935  | 0.74  | 1252 | 1017 |        |
| 11/17 | III | 108.4† | 40 | 109 | 9870  | 1575 | 108   | 9360  | 1460 | 0.835 | 1958 | 1474 | } 1522 |
| 11/17 | IV  | 104.4† | 40 | 113 | 9670  | 1590 | (113) | 9300  | 1450 | 0.80  | 1944 | 1567 |        |
| 11/19 | II  | 110.6* | 40 | 94  | 10400 | 1250 | 92    | 10030 | 1205 | 0.758 | 1612 | 1246 |        |
| 11/20 | I   | 112.9† | 40 | 93  | 10930 | 1170 | 89    | 10560 | 1080 | 0.665 | 1448 | 1341 | } 1292 |
| 11/20 | II  | 111.6† | 40 | 92  | 10700 | 1240 | 91    | 10275 | 1185 | 0.733 | 1584 | 1248 |        |
| 11/20 | III | 112.9* | 40 | 93  | 10500 | 1350 | 90    | 10200 | 1160 | 0.73  | 1552 | 1490 | } 1413 |
| 11/20 | IV  | 112.2* | 40 | 94  | 10300 | 1300 | 93    | 9900  | 1230 | 0.78  | 1642 | 1338 |        |

## CAR S—WEIGHT 205,300 LBS.

|       |     |        |    |       |       |      |       |      |      |       |      |      |        |
|-------|-----|--------|----|-------|-------|------|-------|------|------|-------|------|------|--------|
| 10/26 | IV  | 111.6  | 40 | 103.1 | 9630  | 1425 | 102.1 | 9000 | 1380 | 0.86  | 1848 | 1513 |        |
| 11/13 | I   | 100.9† | 36 | 102.8 | 9600  | 1382 | 101.8 | 9000 | 1269 | 0.8   | 1692 | 1300 | } 1303 |
| 11/13 | II  | 100†   | 36 | 109   | 9200  | 1450 | 108.0 | 8600 | 1380 | 0.857 | 1848 | 1307 |        |
| 11/13 | III | 102.2  | 36 | 86.0  | 9700  | 1060 | 85.4  | 9310 | 1000 | 0.724 | 1333 | 1147 | } 1142 |
| 11/13 | IV  | 102.2  | 36 | 83.2  | 9600  | 1065 | 83.0  | 9100 | 1010 | 0.77  | 1350 | 1137 |        |
| 11/14 | III | 102.2  | 36 | 88.0  | 9400  | 1100 | 87.4  | 8900 | 1040 | 0.77  | 1391 | 1186 | } 1128 |
| 11/14 | IV  | 102.2  | 36 | 83.0  | 9440  | 1030 | 82.4  | 9000 | 1000 | 0.777 | 1333 | 1072 |        |
| 11/23 | I   | 104.5  | 36 | 85.4  | 10150 | 1100 | 83.5  | 9700 | 1040 | 0.74  | 1391 | 1265 |        |
| 11/23 | III | 104.1  | 36 | 84.5  | 10100 | 1080 | 83.7  | 9600 | 1020 | 0.73  | 1363 | 1234 |        |
| 11/26 | I   | 106.6  | 36 | 87.4  | 10250 | 1140 | 86.9  | 9420 | 1080 | 0.762 | 1443 | 1161 | } 1238 |
| 11/26 | II  | 106.3  | 36 | 90.0  | 10000 | 1185 | 89.5  | 9500 | 1145 | 0.776 | 1534 | 1312 |        |
| 11/26 | III | 106.3  | 36 | 87.0  | 10050 | 1125 | 86.5  | 9540 | 1070 | 0.75  | 1431 | 1148 | } 1237 |
| 11/26 | IV  | 106.0  | 36 | 88.5  | 9800  | 1180 | 88.0  | 9300 | 1140 | 0.805 | 1528 | 1322 |        |
| 11/26 | V   | 106.3  | 36 | 85.6  | 9900  | 1090 | 84.2  | 9350 | 1050 | 0.77  | 1403 | 1123 | } 1236 |
| 11/26 | VI  | 105.6  | 36 | 92.0  | 9640  | 1210 | 91.5  | 9060 | 1170 | 0.81  | 1568 | 1343 |        |

\* Car without nose.

† Car with 97,600-lb. sleeper.

‡ Car with nose.

ACCELERATION-PERIOD. TABLE OF THE ELECTRICAL AND MECHANICAL MEAN VALUES.

| Date.<br>1903.           | Run<br>No. | Starting Station. | Level Above the Sea. |               | Distance<br>of<br>Accelera-<br>tion,<br>Feet. | Duration<br>of<br>Accelera-<br>tion,<br>Seconds. | Maximum<br>Speed,<br>Miles p. Hr. | Mean<br>Accelera-<br>tion,<br>Mi. p. Hr.<br>p. Sec. |
|--------------------------|------------|-------------------|----------------------|---------------|-----------------------------------------------|--------------------------------------------------|-----------------------------------|-----------------------------------------------------|
|                          |            |                   | Beginning,<br>Feet.  | End,<br>Feet. |                                               |                                                  |                                   |                                                     |
| CAR A—WEIGHT 206500 LBS. |            |                   |                      |               |                                               |                                                  |                                   |                                                     |
| 10/28                    | I *        | Marienfelde       | 158.4                | 140.5         | 44150                                         | 360                                              | 130                               | 0.363                                               |
| 11/12                    | IV *       | Zossen            | 131.3                | 138.85        | 41280                                         | 393                                              | 107.8                             | 0.275                                               |
| 11/14                    | I *        | Marienfelde       | 158.4                | 148.2         | 17500                                         | 220                                              | 96.8                              | 0.440                                               |
| 11/17                    | III †      | “                 | 158.4                | 138.2         | 33130                                         | 360                                              | 107.8                             | 0.300                                               |
| 11/20                    | I †        | “                 | 158.4                | 129.9         | 28050                                         | 270                                              | 112                               | 0.415                                               |
| 11/20                    | III *      | “                 | 158.4                | 155.7         | 27970                                         | 280                                              | 111.6                             | 0.398                                               |
| 11/25                    | II †       | Zossen            | 131.3                | 156.5         | 40280                                         | 365                                              | 126.9                             | 0.344                                               |

CAR S—WEIGHT 205300 LBS.

|       |     |             |       |        |       |     |       |       |
|-------|-----|-------------|-------|--------|-------|-----|-------|-------|
| 10/23 | IV  | Zossen      | 131.3 | 154.8  | 46820 | 374 | 127.6 | 0.342 |
| 10/26 | IV  | "           | 131.3 | 138.5  | 40810 | 410 | 111.6 | 0.275 |
| 11/13 | I † | Marienfelde | 158.4 | 138.38 | 32960 | 350 | 100.3 | 0.256 |
| 11/13 | III | "           | 158.4 | 160.5  | 20600 | 230 | 100.3 | 0.438 |
| 11/25 | III | "           | 158.4 | 131.9  | 49680 | 400 | 129.4 | 0.324 |
| 11/26 | III | "           | 158.4 | 158.5  | 24980 | 265 | 105.4 | 0.398 |
| 11/26 | V   | "           | 158.4 | 157.9  | 25100 | 280 | 105.4 | 0.405 |

| Run<br>No. | Electrical Measurements. |                       |        |      |                  |        |      |      |              |      | Wind.      |                            |
|------------|--------------------------|-----------------------|--------|------|------------------|--------|------|------|--------------|------|------------|----------------------------|
|            | Fre-<br>quency.          | At Distributing Pole. |        |      | At the Trolleys. |        |      |      |              |      | Direction. | Velocity<br>Ft.<br>p. Sec. |
|            |                          | Amp.                  | Volts. | K.W. | Amp.             | Volts. | K.W. | P.F. | K.W.<br>Hrs. | H.P. |            |                            |

CAR A—WEIGHT 206500 LBS.

|       |    |     |       |       |     |       |      |       |     |      |        |       |
|-------|----|-----|-------|-------|-----|-------|------|-------|-----|------|--------|-------|
| I *   | 48 | 132 | 10410 | ..... | 132 | 10110 | 2040 | 0.88  | 205 | 2726 | E.     | 3.57  |
| IV *  | 40 | 112 | 9840  | 1570  | 112 | 9000  | 1440 | 0.825 | 162 | 1932 | W.     | 10.71 |
| I *   | 36 | 118 | 8910  | 1420  | 118 | 8910  | 1390 | 0.765 | 98  | 1862 | E.     | 7.82  |
| III † | 40 | 146 | 8750  | 1840  | 146 | 8670  | 1760 | 0.80  | 186 | 2285 | S.S.W. | 7.15  |
| I †   | 40 | 126 | 9925  | 1650  | 124 | 9810  | 1590 | 0.756 | 126 | 2125 | N.N.E. | 5.81  |
| III * | 40 | 118 | 9850  | 1600  | 117 | 9705  | 1570 | 0.80  | 131 | 2105 | N.N.E. | 5.81  |
| II †  | 46 | 126 | 10980 | 1935  | 126 | 9840  | 1760 | 0.82  | 186 | 2355 | S.W.   | 7.15  |

CAR S—WEIGHT 205300 LBS.

|     |    |       |       |      |       |       |      |       |       |      |        |       |
|-----|----|-------|-------|------|-------|-------|------|-------|-------|------|--------|-------|
| IV  | 46 | 134.4 | 12015 | 2320 | 134.2 | 10160 | 2130 | 0.9   | 220   | 2855 | S.S.W. | 10.95 |
| IV  | 40 | 113.5 | 9380  | 1520 | 112.8 | 8050  | 1415 | 0.9   | 161.2 | 1896 | S.E.   | 7.37  |
| I † | 36 | 125.2 | 9120  | 1650 | 124.8 | 8900  | 1572 | 0.815 | 152.6 | 2100 | E.S.E. | 7.37  |
| III | 36 | 120   | 8865  | 1525 | 119.5 | 8730  | 1490 | 0.825 | 95.2  | 1992 | E.S.E. | 7.37  |
| III | 46 | 134.3 | 10630 | 2090 | 134   | 10240 | 2010 | 0.845 | 223   | 2685 | S.W.   | 7.15  |
| III | 40 | 115.5 | 9190  | 1530 | 114   | 9000  | 1490 | 0.839 | 109.6 | 1996 | S.W.   | 13.19 |
| V   | 40 | 118.0 | 9040  | 1550 | 117.7 | 8785  | 1520 | 0.853 | 109.8 | 2035 | S.W.   | 13.19 |

\* Without nose.

† With 97,600 lbs. sleeper.

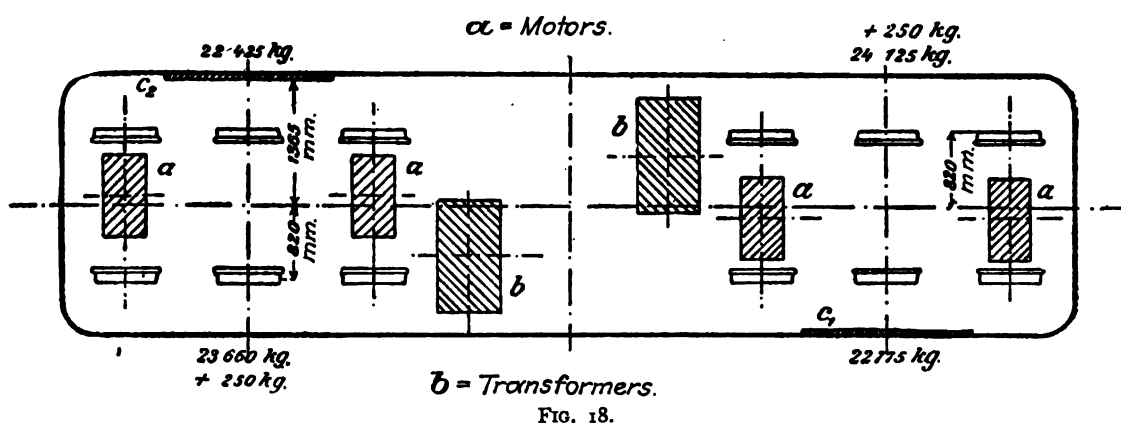
‡ With nose.



less than that indicated by the instruments. The influence of cross winds is to be considered as to these deviations. From the measurements of November 26th, according to which the power at the driving-wheels in one direction differs by nearly 200 metric H.P. (199.2 H.P.) from that in the other direction, and the power used for each of the three runs in the one direction was approximately the same, it must be concluded that this difference was caused by the influence of the wind. The mean values calculated from runs in each direction, as given in the last column, check up well and probably come nearest to the real power consumption reduced to the horizontal and to the calm air. The electrical measurements check up well with the measurements of the torque on car S, given on Plate XXXVI. A comparison of the readings gives an efficiency of the electrical equipment of about 0.88. The difference in power consumption of a car with and without noses can be seen in the table containing the calculation from the electrical measurements. In the table we find on November 20th four test runs with car A; on the first two runs the car was equipped with noses, which were then quickly detached, in order to be able to make on the same day, under the same weather conditions, two runs without noses. As the values show, the car with noses consumed, at a speed of about 181 km. (112.1 miles) p. hr., 121 metric H.P. (119.2 H.P.) less than without, corresponding to a reduction of resistance of 182 kg. (400 lbs.), or 8½%. Approximately the same results were obtained by the coasting tests (page 31). The power consumption of the motor-car with a six-wheel double-truck sleeper weighing 44.3 metric tons (48.8 tons) as trailer is given on Plates XIX and XXIX. At a speed of about 182 km. (112.9 miles) per hour the total power consumption was about 1325 metric H.P. (1304 H.P.). The sleeper alone consumed about 210 metric H.P. (206.5 H.P.), corresponding to a resistance of 350 kg. (771 lbs.). At a speed of about 172 km. (106.4 miles) p. hr. the total power consumption amounted to about 1540 metric H.P. (1520 H.P.), of which about 260 metric H.P. (256.5 H.P.) were used by the sleeper. The resistance at the above speed of the latter alone was therefore 400 kg. (880 lbs.). Finally, it may be noted, as it was on page 19 of last year's report, that the difference between the train resistance as found by the electrical measurements and by the coasting tests is caused by the air resistance of the sliding bows, which were on the wires when the electrical measurements were made and off during the coasting tests.

## 4. Behavior of the Car During Service.

While car S ran very steadily and quietly at the higher speeds, car A began at speeds of 150 km. (92.9 miles) to swing laterally, causing sometimes an interruption in the collecting of the current, and endangering in this way the overhead line. As the two cars were similarly built, the cause of this could only be the unequal distribution of the weight on car A. In car A the center of gravity of the motors did not lie in the middle of the driving-axles, but somewhat on one side, and the two transformers, instead of being on the center line of the car, were placed on one side of this line. In order to investigate the effects of the unequal loading of the trucks by this arrangement, car A was weighed accurately by means of Ehrhardt scales, the points of support being chosen at a distance of 820 mm. (32.2 inches) from the center line of the car. The distribution of the weight on the car upon the wheels is shown in Figure 18. The



differences which were found in the load on the different sides of the truck in front and rear, as well as at the right and at the left, are principally caused by putting the transformers on the sides, whereas the effect of the motors being on one side of the car axles did not amount to very much and was balanced by adding additional weights of 250 kg. (550 lbs.) for each of the motors on the lighter side. The balancing of the unsymmetrical distribution caused by the transformers was obtained by counterweights  $C_1$  and  $C_2$ , which were put on the side of the car body at a distance of 1365 mm. (53.2 inches) from the center line of the car. The weights were calculated as follows:

$$C_1 = 820 \frac{(24,125 + 250 - 22,775)}{1365} = 960 \text{ kg. (2112 lbs.)},$$

and

$$C_2 = 820 \frac{(23,660 + 250 - 22,425)}{1365} = 890 \text{ kg. (1960 lbs.)}.$$

After the installation of these balancing weights the swaying of the car body ceased and did not reoccur even at the highest speeds, and this investigation confirmed the fact which is often overlooked that cars for high-speed service run smoothly only when the load is equally distributed upon the axles. The greater length and the lateral play of the new swivel trucks as compared with the former ones, as well as the transferring of the support of the car body from the swivel bolt to the side frames, have proved their worth, and both cars are now running smoother at a speed of 200 km. (124 miles) p. hr. than well-balanced cars on the through trains do at a speed of 100 km. (62 miles) p. hr. This success can be attributed not only to the heavier track construction and to the good condition of the rails, but also to the suitability of the trucks, as will be learned from the following example: Sleeping-car No. 78 of the State Railroads, weighing 44.3 metric tons (48.8 tons) and having two six-wheeled trucks with cradle springs and a wheel distance of 3.65 m. (12 feet) on the trucks and a total wheel distance of 17 m. (55.8 feet), was pulled by the high-speed cars at different speeds. Up to a speed of 160 km. (100 miles) the sleeping-car ran very smoothly, but at 180 km. (111.4 miles) it began to sway so much that the tests had to be stopped.

The lateral play of the trucks with reference to the car body, as a maximum, was 30 mm. (1.18 inches) on each side, and when entering the sharp curves at the highest speeds this maximum was reached. When entering the curve, the front truck of the car followed the curvature of the track, while the car body continued to run straight ahead until the tension of the flat springs installed to keep the body in the middle position became great enough to overcome the inertia of the car body; then the latter swung over to the other side of the middle position with a slight shock and ran smoothly from there on. To a smaller extent similar effects were felt on the open stretch in places where the track was uneven. This can readily be seen on Plate XXXVII, showing in seven-tenths full size the records of the lateral movements of the middle bolt of the front truck with reference to the car body, taken during the runs. The two other curves were recorded on two different runs in the same direction with a speed of from 200 to 208 km. (124 to 128.6 miles). The two greater deflections from the middle position shown on

this plate occurred when entering the curves. The smaller ones on the open stretch and each deflection of the first run occurred exactly at the same place on the stretch and has the same value as in the second run. The lower curve was taken at a speed of 170 km. (105.5 miles), and in comparing it with the two other curves, it becomes evident that the values of these movements increase considerably with the speed, and though not objectionable up to speeds from 200 to 210 km. (124 to 130 miles), at still higher speeds will set a limit which can not be exceeded on account of the danger of derailment.

#### 5. Behavior of the New Road-bed During the Tests.

The new road-bed of the Marienfelde-Zossen line gave good satisfaction notwithstanding that the test runs were begun immediately after its completion. No deformations of the track occurred and there was no maintenance work during the test except a slight bit of leveling in certain places. In order to record the movements of the rails during the runs, the measuring apparatus using lead plates, as described in the first report, was installed in the curve of 2000 m. (6560 feet) near Mahlow. The results of such measurements are shown in half size on Plate XXXVIII, and it can be readily seen that the lateral movements of the rails were extremely small even in the curve. The vertical movement of the rail reach about 3 mm. (0.118 inch), which is very small, and are caused by the ties sinking into the road-bed. No bending of the rails was observed, as the spacing of the ties was very short. From all the measurements and experience with the road-bed during the test period, it can be concluded that the track is fit to withstand the strain even at these high speeds, and that no extraordinary wear of the road-bed and tracks is to be expected. In the curves of 2000 m. (6560 feet) radius generally a speed of only 160 km. (100 miles) was maintained, but even at speeds of 170 to 180 km. (105.5 to 111.7 miles) no dangerous effects on the rails were observed. The elevation of the outer rail, which amounts to 80 mm. (3.14 inches) on these curves, was primarily equalized upon a length of 50 m. (164 feet), but for the higher speeds this length was not sufficient, and when entering the curve a shock was felt every time resulting from the one-sided lifting of the car. The ramp had therefore to be decreased to 1:1200 (100 m. long (328 feet)) instead of 1:200, as is the usual practice, and when this was done the shocks entirely disappeared. According to these experiments the new road-bed of the Prussian State Railways with rails profile No. 8 and 18 ties distributed over a rail length of 12 m. (39.36 feet)

is sufficient in every respect for running with absolute smoothness up to speeds of 160 km. (100 miles p. hr.), provided the load on each wheel does not exceed 8 metric tons (8.8 tons) and that the distance between wheel centers is sufficiently great. For still higher speeds it is believed that guide-rails similar to those used in the tests are the best means of carrying heavier weights and of increasing the strength of the track. The same purpose could be attained by using a solid road-bed for the track, or by the use of very much heavier rails, but the cars would not run so smoothly and easily as at present. Besides, the guide-rails have the advantage of adding to the safety at these high speeds. At present we have not sufficient observations and experience to be able to decide this question.<sup>1</sup> There is no doubt that such guide-rails are necessary on the curves, as they prevent the outside front wheel from climbing the rail, and also on the open stretch these guide-rails add largely to the safety of the service. Several derailments of fast trains on the open stretch which occurred on the German railroads in the last few years have apparently been caused by the climbing of the wheels upon the rails, due to irregularities in the track. In these cases the height of the wheel-flanges was not sufficient to prevent the derailment of the cars, and it was recommended that this height of the wheel-flanges be increased, but this could not be done without changing all the switches and frogs of the track. The danger of derailment from irregularities of the track increases rapidly with the increase of the speed, and it seems to be advisable to use guide-rails on the open stretch for speeds of more than 160 km. (100 miles) p. hr.

### III. FINAL REMARKS.

The work which the "Studiengesellschaft" had planned at its organization was brought to a successful close in the fall of the past year by the united efforts of all people interested after a period of three years. During the numerous and successful test runs, speeds up to 200 km. (124 miles) p. hr. were often reached, and during the whole test period not a single accident occurred. The tests have proved that by using high-tension alternating current and specially constructed equipment, it is possible to run with safety at these heretofore unattained speeds upon tracks of good construction. Who would have foreseen this development twenty-five years ago when on March 31, 1879, Siemens & Halske showed at the Berlin Industrial Exposition the first electrical locomotive in service in the world? The great success of German engineering, its perseverance and great sacrifices, have excited much interest and received

recognition far beyond the boundaries of Germany. These tests started a movement of great importance. To-day we find everywhere an effort to improve passenger transportation on railroads, both as to speed and number of trains. The general public is now beginning to realize the value of the work of the "Studiengesellschaft," and the question is, "What further can be done in order to utilize the valuable technical results obtained from these experiments in the development of long-distance electric roads"? According to the suggestion of the Executive Committee, the Directors of the "Studiengesellschaft" decided to continue these tests. Experience shows that it is not good policy to give up such a promising enterprise, but to continue it with all possible efforts, as otherwise the work done and the money spent might be lost. Besides, the "Studiengesellschaft" seems to be destined to keep up the interest for high-speed electric service as well as to combine all endeavors with the same aim, and it is to be hoped that the "Studiengesellschaft" will enjoy in the future as it has in the past the good-will and the assistance of the State Government.

The purpose of further tests will be to gain, by a series of endurance tests based upon the present experience, further practical results, especially in relation to the application of single-phase current. These results can then be adapted to the construction and service of high-speed electric railways, and the proof be given that electric service is superior to steam as to speed and general efficiency and is fully as economical. The Marienfelde-Zossen line of the Military Railroad is not well fitted for endurance tests on account of the insufficient length of the stretch, and it would be more favorable if a long stretch could be built, perhaps as a section of a future long-distance railway. For the time being only the Military Railroad can be considered for the continuation of the tests, as the Government has agreed to let the "Studiengesellschaft" have the further use of this road.

The Oberspree Central Station is at the present time heavily overloaded on account of increased demand arising from the reduction in the price of power, and will therefore not be able to furnish current for the tests, unless new generators are installed in the near future. The tests must therefore be postponed until sufficient power is obtainable, and in the meantime new plans and projects will be made and other projects will be examined and studied.

Different lines have been proposed for the practical construction of a high-speed railway, as Berlin-Potsdam, Frankfurt-Wiesbaden, Bruessel-Antwerpen, Manchester-Liverpool, etc. Besides, the two electrical firms belonging to the

"Studiengesellschaft" have worked out an interesting report concerning the project of a high-speed railway between Berlin-Hamburg, basing this report upon the experience gained in the tests and making a detailed statement of the cost and operating expenses. An extract from this report with a résumé of the results of the calculations is attached to this report, and it is desired that the "Studiengesellschaft" will succeed in the near future in constructing this railway as the first high-speed railway on the continent and a fitting conclusion of its work.

# APPENDIX.

## IV.

EXTRACT FROM THE REPORT OF THE "ALLGEMEINE ELEKTRICITÄTS GESELLSCHAFT" AND THE "SIEMENS & HALSKE AKTIENGESELLSCHAFT" CONCERNING A HIGH-SPEED ELECTRIC RAILWAY BETWEEN BERLIN AND HAMBURG.

### 1. Introduction.

IN public, business, and private life neither the telegraph, the telephone, nor the excellently arranged postal service can fully replace personal communication. The reason the traveling is restricted only to cases of utmost necessity is not because of the expense involved, but the great loss of time which traveling necessitates. In addition to this comes the fact that only a few through trains are run daily between important large cities. The traveling man must make his arrangements according to these circumstances, and it mostly happens that the leaving and arriving time of the trains derange his usual plans for the day and traveling during the night and staying overnight can not be avoided. It certainly would answer a very urgent necessity if the time spent in traveling could be shortened and if more frequent opportunities were given. Considerable increase in the passenger traffic and a greater desire to travel would be the result, and the mutual relations of cities connected by frequent high-speed trains would grow to an extent unrealized and unforeseen to-day. The development of suburbs and surrounding boroughs of Berlin, which have grown to an importance which a few years ago would not have been dreamed of, can be given as an example. Frequent but yet slow train communications have created a "Greater Berlin," with extensive and new business and traffic relations. In the same way high-speed and frequently running trains would be of the greatest commercial importance for two cities situated a great distance apart. The effect of a high-speed railway upon the traffic and the whole commercial life of two great cities connected by it can be compared to the opening of a bridge which connects two cities across a large river, where before all the traffic had to be done by ferry-boats. Such a railway can bring two distant cities so close together that they become almost "sister cities."



The question of how to bring about such a high-speed traffic, which has been discussed quite frequently in public life, has had only a theoretical importance as long as the industry was not able to give full proof that such a high-speed traffic could be realized with absolute safety and without exorbitant cost. This proof has been given by the "Studiengesellschaft" for high-speed electric railways, and based upon the favorable results obtained in their tests, the two electrical firms belonging to the above society undertook the task of investigating the practicability of a high-speed railway for a special case.

## 2. Selection of a Line.

For such a high-speed railway only commercial and industrial centers with active and wealthy populations and already existing important traffic relations can be considered, and from this standpoint, the two greatest cities of Germany, the capital and the main port of the German Empire, Berlin and Hamburg, seem to be specially fitted for connection by a high-speed railway.

Berlin, together with the cities and communities in its close vicinity, has a population of two and a half million inhabitants and is, as the capital of the Empire, the central point of all the railroads running to the other capitals, great cities, and provinces. Berlin is also the center of the Governmental Administration and of the Military Organizations of the Empire. At the same time it is without the slightest doubt the first industrial town of the Empire, perhaps the first on the Continent, and manufactures on a large scale goods which are specially intended for exportation. As a commercial center Berlin stands first among the interior towns of the German Empire. On the other hand, Hamburg, together with Altona, with nearly one million inhabitants, is the largest port of the German Empire. It occupies a natural place of exchange for the official business and individual relations of German citizens with foreign countries.

The construction of a high-speed railway between Hamburg and Berlin would be especially practicable on account of the great distance between these cities, as in this way the time gained could be entirely utilized in the most beneficial way and the journey could be shortened to such an extent that the staying overnight and the spending of two days for the trip could be avoided in most cases. Based upon these conclusions the two electrical firms finally considered the construction of a high-speed railway between Berlin and Hamburg.

### 3. The Two Projects.

The two projects for the high-speed electric railway, Berlin-Hamburg, worked out by the two electrical firms, Siemens & Halske Aktiengesellschaft and the Allgemeine Elektrizitäts Gesellschaft, differ only as to the extent of the enterprise, as explained below. As the purpose of the Siemens & Halske project is to cut down as much as possible the amount of capital necessary for this enterprise, their project does not provide for the construction of independent tracks in entering the two cities, and it is supposed that the high-speed trains will enter these cities upon the tracks of one of the existing railways running at a moderate speed between the steam trains, because in the beginning it will not be necessary to run the high-speed trains at very short intervals. Further, it is intended to build this high-speed railway as a single-track road since it is planned to run the high-speed trains in the first year at two-hour intervals, which schedule would not necessitate a double-track road provided that the trains stop and cross in the middle of the stretch at Wittenberge. The road is to be laid out in such a way that a second track can be put in if necessary without difficulty, and the possibility of building a special track later on for entering the cities independently of the other railroads has been considered. The Allgemeine Elektrizitäts Gesellschaft based its project upon the assumption of a more intense traffic at the start than that assumed by the Siemens & Halske Company, and proposes therefore to run the trains at intervals of half an hour, which makes it necessary to build a double-track road without stop on the stretch and with separate roads for entering the cities and special terminal stations.

### 4. Selection of the Motive Power.

The speeds attained upon the present railroads do not exceed 90 km. p. hr (55.8 miles), and the most recent tests have proved that a higher speed than 120 km. p. hr. (74.6 miles) can hardly be attained with trains hauled by steam-locomotives. As the power increases at a higher ratio than the square of the speed at higher speeds, it would be necessary to use locomotives of such large dimensions that a large part of the motive power would be used in driving them alone, and thus the service would not be commercially practicable. Steam has therefore not been considered in these projects for the high-speed railway and electricity has been provided as motive power for hauling the trains.

For the existing electric railways direct current is generally used for driving the motors in the cars, yet for high-speed railways this kind of current does not seem to be suitable, as the direct-current voltage is limited, and as the transmission of such great quantities of electrical energy as required for the driving of high-speed trains involves for long distances numerous difficulties and great expense. New prospects for the application of electricity to train service were presented after the electrical engineers succeeded in applying alternating current directly to railway motors. The possibility of using high voltages which can be transformed according to the demand without very great cost, makes alternating current especially fit where large quantities of energy have to be transmitted over long distances; i.e., in just such cases as high-speed railways.

In realizing these facts the "Studiengesellschaft" for high-speed electric railways used on a large scale the three-phase current directly as motive power for the high-speed tests. The results of these unprecedented tests were so favorable as to the distribution and collection of the current from the trolley-line and as to power consumption that there can be no objection to the use of the same methods in practice for the high-speed railways. There is no doubt that also the single-phase current, which is now attracting the attention of engineers, may be well fitted for high-speed electric service. The question, Is three-phase or single-phase current to be used? is not of such importance as to make it necessary to decide at the beginning. The cost of installation would be approximately the same in both cases. The single-phase current has probably some decided advantages as compared with the three-phase current, and in any case if used, the calculations would give still more favorable results.

#### 5. Road-bed and Track.

Before the tests of the "Studiengesellschaft" were made nothing was known concerning the wear of tracks by trains running at very high speeds, and it seemed doubtful if the road construction, as used up to the present time, would be satisfactory. The tests of Marienfelde-Zossen have given reliable information upon this point, which can be utilized with full confidence for the construction of a high-speed railway. A heavy road construction consisting of heavy rails mounted on wooden ties well ballasted, as is used on the main lines of the Prussian State Railways, is safe up to speeds of 200 km. p. hr. (124 miles). It seemed to be advisable to build the high-speed railway with a wider gauge than the standard, but for certain reasons this was not done in either of the

projects of the two electrical firms. Each high-speed railway will doubtless always be operated entirely independent of other railways, but it must be made possible in case of emergency to use some of the high-speed cars, if not whole trains, upon the ordinary railroads. For military reasons it is especially desirable that in case of war the ordinary trains could run over the high-speed tracks.

#### 6. Construction of the Cars.

The existing through vestibuled cars, which have given excellent satisfaction, have also been selected for these high-speed trains. This construction makes it possible for the passengers to go from car to car and facilitates supervision of the train by the conductor. The only difference between the through cars now in use and the high-speed cars will be that in the latter case six-wheel double trucks with long distance between axles will be used, guaranteeing in this way greater safety and smoother running of the car, which was proven in the tests of the "Studiengesellschaft."

#### 7. Operation.

The idea presented itself that in order to create a high-speed service between Hamburg and Berlin it would be sufficient to strengthen the present road construction and to meet the increased demand for trains by adding new ones without making any considerable changes in the construction or service of the existing railroad. A glance at the graphical time-table of the Berlin-Hamburg Railroad shows that any sweeping improvements of the traffic conditions would present great difficulties, due to the fact that a great number of trains of very different speeds run on the same track. It seems as if this was the main difficulty in our present railroad service, causing numerous delays, disturbances, and accidents. It is apparent that a high-speed and a freight service can not be conducted over one line. In the present railroad service through trains create a disturbance a long time before and a long time after they pass a station, as according to the present system all through trains have preference over the other trains. If a through train is but a little behind time considerable derangement of all trains results, changing their schedules and the length of the stops at the intermediate stations. In increasing considerably the speed of through trains it becomes an absolute necessity to separate freight and passenger traffic, first, because higher speeds necessitate greater care as to safety, and, secondly,

the effects of the disturbances would become still more apparent as the difference in the speed of the different trains increases. The erection of an entirely new and separate road for high-speed service is therefore a necessity. Beside these considerations as to the service, the construction of the present railroads does not permit of using them at the same time for high-speed service. The strengthening of the track is not the only change necessary: the grade to the existing curves of the road must be made more gradual; the exterior rail must have a higher elevation, corresponding to the higher speed, which makes the operation of slow-speed trains on the same track more difficult.

Another great obstacle is the switches and track-crossings at the different intermediate stations, upon which the cars would have to run at a reduced speed. The frequent reduction of the high speed would result in a considerable loss of time, losing in this way the advantage of a uniform velocity and causing an extra consumption of energy by the repeated braking and accelerating of the trains. All these reasons led to the adoption of an independent road, in the open stretch at least.

The question, if in high-speed service single cars or entire trains are to be given preference, has often been answered from the one-sided standpoint, that the electric service makes it necessary, on account of economy, to divide up the trains into single cars following each other at short intervals. This method has proved to be very successful for the ordinary street-car lines, but it is not at all advisable for long-distance railroads, and especially high-speed service. This system causes with the increasing number of cars a considerable increase of the expenses of the personnel. Also the operating expenses are considerably higher in running single cars instead of entire trains with the same number of seats for the following reasons: At high speeds the air resistance at the head end of the car forms the largest part of the total train resistance, and is, therefore, proportionately larger for a single car than for an entire train. Compared with this head-end air resistance the influence of the friction of the air on the sides of the car and the influence of the rail friction is very small. The difference in power consumption at high speed for running a single car or a motor-car with one or more trailers will, therefore, not be very large. The single-car service is also more expensive as to the first cost, as in this case all the cars have to be equipped with motors, switches, etc. This service offers, therefore, no advantages either as to cost of construction or economy of operation, and for these reasons a service with short trains has been provided, the trains consisting of one motor-car and from two to four trailers.

Many travelers suffer a loss of their valuable business time in being compelled to take their meals before starting or after arriving at a station. It is, therefore, a great saving in time and a great convenience for the traveling public if they can take their meals on the trains, an arrangement which has given very good results on the existing railroads. The motor-car of the high-speed train of Siemens & Halske has room for a kitchen and a large dining-room. As all the cars of the train are connected to the motor-car by vestibules, edibles and drinks can be served in all the compartments of the trailers. The intention is to run this high-speed line, Berlin-Hamburg, at a speed of 160 km. (100 miles) p. hr. at the beginning, and in accordance with the tests at Berlin-Zossen, there can be no objection to raising the speed with increasing traffic to 200 km. (124 miles) p. hr., and the road has, therefore, been designed for this high speed. The high speed and the short headway of the trains make it necessary to avoid all grade crossings. All crossings over city or country roads have, therefore, to be made either above or below the tracks.

#### 8. Estimate of the Traffic.

In order to predetermine the anticipated traffic of the high-speed railroad between Berlin-Hamburg with some degree of accuracy, it is not sufficient to obtain the data concerning the present traffic on this line. A certain increase of the traffic must be looked for on account of the improved traveling facilities of this high-speed railway. In order to make a fair estimate it is necessary to refer to similar cases, but as high-speed railroads do not exist at the present time it is somewhat difficult to obtain the necessary data on the subject. The results obtained on the Mailand-Varese Railroad are very instructive in this respect. This railroad was changed over from steam to electricity and the speed increased from 30 and 40 to 45 and 60 km. (18.6-24.8 to 27.9-37.2 miles) p. hr., increasing at the same time the number of trains. The results obtained as to passenger traffic are given in the following report:\*

"The results obtained with the electric service exceeded all expectations. The great speed and the regularity of the service as well as the greater number of trains caused the public to give the preference to the electric cars running parallel with the steam-trains, resulting in a considerable increase in the passenger traffic. At the beginning of the service seven electric trains were run in each direction between the steam-trains, and on November 20, 1901, the number of electric trains in each direction between Mailand-Gallarate had to be increased

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\* Zeitschrift fuer Kleinbahnen, Heft 9, Jahrgang 1903.

to nineteen and between Gallarate-Varese to fourteen. But this increase was still not sufficient on account of the constantly growing passenger traffic, so that finally, beginning June 16th, 1902, thirty-two electric trains were run in each direction between Mailand-Gallarate and twenty-three between Gallarate-Varese. On special holidays and market-days a great number of extra trains had to be put in service. At the beginning the trains consisted of only two cars, but as these two cars were constantly overcrowded, and as the freight and baggage traffic increased continually, it was necessary to increase each train to at least three cars, and finally to nine each. The greatest number of electric trains was run on September 8, 1902, at the time when this report was made, amounting to a total of eighty-six. As it was not possible to accommodate all the passengers, and as no other electric cars were available, it was necessary to run some steam-trains in addition.

"In the first year of the electric service 11,000,000 'car-axle km.' (6,835,000 car-axle miles) were run as compared with 4,769,896 (2,960,000) with steam service in 1897. The total earnings of the passenger traffic in the time from December 1, 1901, to August 1, 1902, was, in spite of the reduction in rates, 993,150 liras (\$198,630) as compared with 660,000 liras (\$132,000) in the preceding year. The increase in profit to the Government for nine months of this electric service as compared with the whole preceding year was 230,552 liras (\$46,110.40)." These favorable results gain in value when considering the fact that they were obtained at a time of general commercial depression. The Mailand-Varese Railroad can not very well be compared as to its importance with the high-speed Berlin-Hamburg Railway, and the increase of speed of the former is far much less than the intended increase on the latter, but the results obtained with this Italian railway justify the greatest hopes for the development of the Berlin-Hamburg Railway.

Another parallel can be drawn between the increase of the passenger traffic at the time of the introduction of the railroads, replacing the stage-coach, and the expected increase in case that the high-speed service replaces the present railway service. In both cases a more rapid, more frequent, more convenient means of transportation was substituted for the older one, saving time and energy of the traveling public.

The first railroad entering Berlin was the Berlin-Potsdam Railroad, the opening of which took place at the end of 1838. This new enterprise was not looked on with very much favor at the time of its foundation, and King Friedrich Wilhelm III. is quoted as saying the following:

"I can not derive any very great happiness from the possibility of arriving a few hours earlier in Potsdam."

The Postmaster-general, von Nagler, who, as the head of the Prussian Department of Traffic at that time, is certainly to be considered as an expert, made the following remark concerning the new Berlin-Potsdam Railroad enterprise:

"Nonsense. I have several six-seat stages running daily to Potsdam and nobody rides. Now these people want to build a railway to this town. If they want to get rid of their money, I propose that they throw it out of the window before they spend it in such a foolish enterprise."

Fortunately it is possible for us to give data upon the passenger traffic between Berlin-Potsdam. In a report made by the Postmaster-general, von Nagler, to the King on August 15th, 1835, the former expresses his fear that the stage service between Berlin-Potsdam will be entirely deprived of the local passenger traffic by the railroad, causing a loss in the gross income of 17,000 thaler (about \$10,200) a year. In assuming a rate of 8 pfennig p. km. (about 3.22 cents p. mile) for the ordinary stage and 13 pfennig p. km. (5.24 cents p. mile) for the express stage, i.e., 10 pfennig as an average p. km. (about 4.02 cents p. mile), and taking the distance between Potsdam and Berlin as about 30 km. (18.6 miles), the number of passengers would be 17,000 per year.

Everybody will understand that such a traffic would not pay for a railroad, but the organizers of the Berlin-Potsdam Railroad had better hopes regarding the new enterprise than the experts and the population. According to their estimate of May 1st, 1835, they expected to have a traffic of 118,000 passengers per year. Yet during the first year of operation, 1839, the number of passengers carried was 664,828; but this number fell somewhat in the next years on account of the commercial depression, and because at first many people rode out of sheer curiosity. After the Berlin-Potsdam-Magdeburg Railroad had been joined with the Magdeburg-Halberstadt Railroad the traffic began to increase. The traffic on this railroad had, therefore, from the very first surpassed that of Nagler's six-seat stages 39 times and the estimates of the organizers 5½ times. An entire change of public opinion as to this enterprise soon took place, and even King Friedrich Wilhelm the III. began to use the railroad, which he had avoided entirely at the beginning. In our quiet Germany, which had at that time no industry and commerce of any importance, in the country of the poets and philosophers, the necessity was felt and the capital was found for building rail-



roads, doing away with the old poetical way of traveling with the stage. In a very short time new railroads were built having Berlin as a center, and also in the provinces tracks were laid to connect the most important cities of the country. King Friedrich Wilhelm the IV., while Crown Prince, did justice to this progress in saying, as he was riding on a locomotive of the Berlin-Potsdam Railroad, the following prophetic words: "This cart, running through the world, can not be stopped by the arm of man." These historical reminiscences are not without value. They give proof of the enormous revolution caused by increasing the speed of traveling three or four times as compared with the former well-organized stage service.

(Remark: The maximum speed of the stage was 10 km. (6.2 miles) p. hr., and of the first railroads from 30 to 40 km. (18.6 to 24.8 miles) per hr.) It is worth noticing that this new means of transportation met with distrust in the beginning and then suddenly an entire revolution of the opinion concerning this new system took place notwithstanding that the first railroads did not have very many of the modern conveniences. The tickets at the opening of the Potsdam Railroad had to be bought in a book-store in the city. The station was situated outside of the city walls, at those times a long distance from the center. The third-class cars were open and the second-class cars were closed and provided with ordinary seats. The people of rank remained in their own carriages, which were put on top of one of the open cars, and rode with the proud feeling of possessing such a carriage. In spite of these primitive methods of transportation, and in spite of the moderate speed of these trains, which necessitated a law prohibiting people from following them, nothing could stop the enormous growth of traffic, which made its way with an irresistible impetus and creating those times which were noted as standing under the "era of railroads."

We have treated this example of the Potsdam Railroad at length purposely because it is of special value in judging the anticipated traffic for the Berlin-Hamburg high-speed railway. In both cases it is a question of connecting a large and smaller city which have an active mutual relation capable of growth.

The journey between Berlin-Potsdam took at that time from three to five hours, while it takes to-day about the same time for a through train to run from Berlin to Hamburg. When the Berlin-Potsdam Railroad was built the time occupied in making the journey was reduced to about one-third the time formerly required. This would also be the case of the high-speed railway between Hamburg-Berlin.

Berlin and Potsdam had together at that time a population of not more than 400,000, while "Greater Berlin" and Hamburg-Altona have to-day a population of 3,500,000.

A similar increase as upon the Berlin-Potsdam line occurred in the traffic of the other lines when the stage was replaced by the railway. As it is somewhat difficult to-day to get the correct data concerning the traffic conditions then existing, we can only give a few examples in order to prove this:

|   | Name of the Line.           | Length.<br>Miles. | Former<br>Passenger<br>Traffic. | Passenger<br>Traffic of the<br>Railway in the<br>First Year of<br>Full Operation. | Ratio between<br>Railway Traffic<br>and Stage<br>Traffic. |
|---|-----------------------------|-------------------|---------------------------------|-----------------------------------------------------------------------------------|-----------------------------------------------------------|
| 1 | Elberfeld-Duesseldorf. .... | 16.7              | 12,000                          | 383,018                                                                           | 32                                                        |
| 2 | Berlin-Potsdam. ....        | 18.6              | 17,000                          | 664,828                                                                           | 39                                                        |
| 3 | Coeln-Aachen. ....          | 43.4              | 16,000*                         | 374,574                                                                           | 23                                                        |
| 4 | Dresden-Leipzig. ....       | 73.2              | 10,000                          | 441,531                                                                           | 44                                                        |

\* Passengers transported in carriages are included.

These figures prove that at the time of the introduction of railroads the existing need for rapid transportation surpassed even the most sanguine estimates, and based upon these data it can be expected that the construction of the high-speed Berlin-Hamburg Railway will be followed by an increase of traffic of from two to three times that at present.

The average number of passengers carried daily on the Berlin-Hamburg Railway in 1902 was as follows:

| Kind of Trains.             | Passenger<br>Traffic in<br>Summer. | Passenger<br>Traffic in<br>Winter. | Average<br>per Year. |
|-----------------------------|------------------------------------|------------------------------------|----------------------|
| Accommodation trains. ...   | 1600                               | 1300                               | 1450                 |
| Fast passenger-trains. .... | 500                                | 400                                | 450                  |
| Through trains. ....        | 1300                               | 700                                | 1000                 |
| Totals. ....                | 3400                               | 2400                               | 2900                 |

showing a little more than a million passengers in both directions.

The traffic of late years has been increasing considerably in all parts of the country, and the through trains experienced the greater part of this increase. Whereas the total traffic during the years of 1900 to 1902 increased about 11%,

the increase in the traffic on the through trains during the same period was more than 20%, and the ratio between the seating capacities of the trains and the actual number of passengers increased in the same way. While in 1900 each through train carried an average of 106 passengers, in 1902 this figure rose to 126; i.e., 20% higher. In 1894 the above ratio was 60% for certain kinds of trains, but taken for all Prussian railroads during the whole year was only 25%.

In the following we will try to give some information concerning distribution of the passenger traffic upon the through and local trains of the Berlin-Hamburg line.

#### THROUGH TRAINS.

According to the above statistics the average number of passengers carried by these trains is about 1000 per day, being somewhat higher on the Berlin-Wittenberge line and somewhat lower on the Wittenberge-Hamburg line. Since September, 1903, a new through train has been added in each direction, carrying about 100 passengers each way, without decreasing to any extent the number of passengers on the other through trains. The total average traffic on the through trains is therefore almost 1200 passengers per day.

The traffic between the intermediate stations of Wittenberge, Ludwigslust, Holgenow, and Buechen has to be deducted from these figures, but it can be considered very small, for the reason that only a few of the through trains stop at these stations. This local traffic probably amounts to a maximum of 5% of the total traffic. The remaining 95%, equal to 1100 passengers daily, is to be counted for the direct through traffic between Berlin and Hamburg.

#### FAST PASSENGER-TRAINS.

These trains take care of the traffic between the larger cities which lie between Berlin and Hamburg, and the number of passengers carried on these trains is subject to great fluctuations, and it cannot therefore be considered with the through traffic between Berlin-Hamburg.

#### ACCOMMODATION TRAINS.

These trains serve generally for the local traffic and for the transportation of fourth-class passengers, yet the two night trains, numbers 205 and 206, are also used by other passengers of the higher classes, as they offer the only possible means of transportation at this time. As the morning trains do not reach the

end of the line before noon, all of the passengers who have some business in Berlin or Hamburg during the forenoon hours, and who wish to avoid staying overnight in a hotel on account of economy, have to use the common night passenger-trains. These trains also have sleepers, the passengers in which are without exception through passengers. These night trains carry an average of 100 passengers and are more crowded in summer than in winter, the number of passengers in both directions being nearly equal. It can be estimated that of the 200 passengers of these trains one-quarter, or 50 passengers, are through passengers. According to these data the through passenger traffic between Berlin and Hamburg amounts to a total of 1150 passengers every day, equal to 420,000 passengers per year in both directions. As the construction of such a high-speed railway would require about six years on account of the different preliminary negotiations, a further increase of the traffic would take place during this time, by which the high-speed railway would be largely benefited. Assuming that the through passenger traffic increases  $7\frac{1}{2}\%$  per year, a figure which is certainly not too high in considering the 10% increase of the last years, the number of passengers based upon the natural development of the traffic would be in the first year of operation 420,000 times 1.075<sup>6</sup>, equaling 650,000 passengers.

#### 9. Commercial Practicability.

The estimates of the two electrical firms conclude with the following sums:

| Projects of Siemens & Halske A. G., Berlin. |               | Projects of Allgemeine Elektrizitäts Gesellschaft, Berlin.                  |                                                                             |
|---------------------------------------------|---------------|-----------------------------------------------------------------------------|-----------------------------------------------------------------------------|
| <i>a</i>                                    | <i>b</i>      | <i>c</i>                                                                    | <i>d</i>                                                                    |
| Single Track.                               | Double Track. | Speed of 100 Miles p. Hr.<br>(Their Own Tracks for<br>Entering the Cities). | Speed of 124 Miles p. Hr.<br>(Their Own Tracks for<br>Entering the Cities). |
| CAPITAL INVESTED.                           |               |                                                                             |                                                                             |
| 217,500,000                                 | \$26,250,000  | \$31,250,000                                                                | \$35,000,000                                                                |

Although the estimates of these two companies have been worked out independently, they come to about the same results. Both companies based their calculations as to the anticipated earnings upon the number of passengers given

above, but it was taken into consideration that such a high-speed railway would greatly improve the traffic between Berlin and Hamburg. Experience teaches us that every improvement causes an increase in our wants. That this maxim also holds good as to traffic was proven by the above examples of the Mailand-Varese Railroad and the substitution of the railroad for the stages. The frequent and rapid train connections of the high-speed railway would cause a further expansion of feeding territory and a change and deviation in the traffic of other railroads. So, for instance, the traffic from Stettin to Hamburg will go still more by the way of Berlin than at present, as this would assure the best connections and the quickest traveling. In the same way the traffic from Berlin to Kiel and Luebeck later on would go by the way of Hamburg, using the high-speed railway, and even more distant cities and districts would be affected by the railroad and benefit the latter. Bremen could be reached quicker by the way of Hamburg in spite of the longer distance than by the present route by way of Stendal-Uelzen or Hanover.

In considering all these circumstances it may be expected that the number of through passengers, which is already 650,000 as based upon the natural development of the traffic, would be increased still more by the construction of the high-speed railway, and probably reach the 2,000,000 mark during the first year of operation. The first project of Siemens & Halske proves that with 520,000 passengers such a high-speed railway between the above cities would be profitable, although, due to reasons given before, the trains would only run at two-hour intervals. With 850,000 passengers per year the construction of the second track would be justified, thus permitting a one-hour instead of a two-hour headway. The main project of the Allgemeine Elektrizitäts Gesellschaft proves that the construction of separate city lines and terminal stations would be justified with about 1,000,000 passengers, giving in this way a better schedule and more frequent trains. With a traffic of 1,200,000 passengers per year the increase of the speed from 160 km. to 200 km. (100 to 124 miles) p. hr. would be profitable. The two projects of the Allgemeine Elektrizitäts Gesellschaft provide trains at half-hour intervals. With such a service, which is similar to the street-car service, an increase of the traffic to several times its present value can be expected. In calculating the earnings higher rates have been assumed than those in force at present. This increase is justified, as a passenger, having the advantage of more frequent and rapid transportation, gains considerably in time and saves an increase in living expenses. The present rates are:

| Class.           | Single-trip<br>Ticket. | $\frac{1}{2}$ Return<br>Ticket. |
|------------------|------------------------|---------------------------------|
| I. Class. ....   | \$6.52                 | \$4.35                          |
| II. Class. ....  | \$4.85                 | \$4.26                          |
| III. Class. .... | \$3.40                 | \$2.17                          |

In addition to these rates a seat rate of two marks (\$0.50) has to be paid for the first and second classes, and a rate of one mark (\$0.25) for the third class. For the high-speed railway it has been planned to use only one class, which would correspond to the present second class. Besides, a few luxuriously equipped compartments will be provided, for the use of which a higher price must be paid.

The price of a one-way ticket is to be 15 marks (\$3.75), and an additional ticket for the special compartments may be had for five marks (\$1.25). The average earning will, then, be about 16 marks (\$4.00) per passenger.

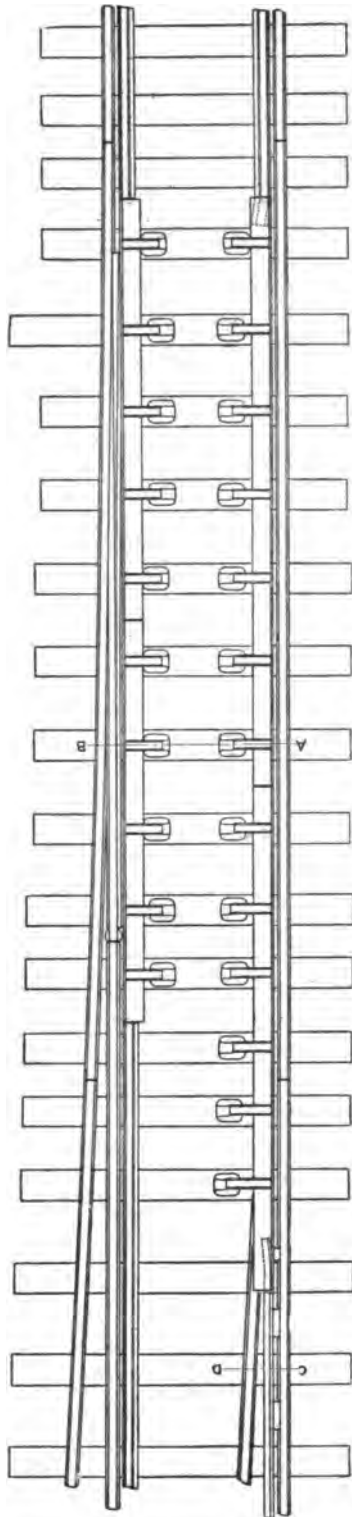
This will be increased by the transportation of baggage, the rents from the train and the station restaurants, the installation of automatic selling machines, and the rental of space for advertising purposes, etc. All these incomes, as well as the receipts from express baggage and express mail, are not included in the calculations, the results of which are given in the following table. For the calculation of the expenses of the high-speed Berlin-Hamburg Railway the figures for the operating expenses of existing electric railways have been used, some of the items having been increased. Besides, a sufficient percentage of the earnings has been put aside for the sinking fund, government and local taxes, and insurance.

Though these expenses have been assumed sufficiently high, another increase of 30% has been made for the first year of operation in order to cover the additional expenses which may arise from inexperienced employees and from other unforeseen causes. Even under these conditions the financial result, as shown in the following table, is absolutely favorable. If later on the operating expenses reach their normal value, the profits will be still larger and a reduction of the rate could be considered.

One half of one per cent of the invested capital is taken from the profits for the sinking fund and 5% of the remainder for the reserve fund required by law; the remainder is then used for the interest on the bonds and for the payment of dividends. The results of these calculations are found in the following

table. These figures prove beyond all doubt that the installation of a high-speed railway between Berlin and Hamburg is justified from a commercial standpoint. In the beginning the enterprise will realize a moderate interest on the invested capital, but in the course of time a favorable increase in the profits may be expected.

|                                                                                                                    | Project of<br>Siemens & Halske A. G., Berlin.     |                     | Project of Allgemeine<br>Elektricitäts Gesellschaft, Berlin.                                                 |                                                                                                                       |
|--------------------------------------------------------------------------------------------------------------------|---------------------------------------------------|---------------------|--------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------|
|                                                                                                                    | a.<br>Single Track.                               | b.<br>Double Track. | c.<br>Main Project, with<br>Speed of 100 Miles<br>p. Hr. (Their Own<br>Tracks for En-<br>tering the Cities). | d.<br>Additional Project,<br>with Speed of<br>124 Miles p. Hr.<br>(Their Own<br>Tracks for En-<br>tering the Cities). |
| Number of passengers per year.                                                                                     | 520,000                                           | 850,000             | 1,000,000                                                                                                    | 1,200,000                                                                                                             |
| Headway. ....                                                                                                      | 2 hours                                           | 1 hour              | $\frac{1}{2}$ hour                                                                                           | $\frac{1}{2}$ hour                                                                                                    |
| Maximum speed per hour . . . .                                                                                     | 100 miles                                         | 100 miles           | 100 miles                                                                                                    | 124 miles                                                                                                             |
| Schedule time. ....                                                                                                | (1 hr. 55 min.)<br>(Incl. stop at<br>Wittenberge) |                     | 1 hr. 47 min.                                                                                                | 1 hr. 25 min.                                                                                                         |
| Capital invested. ....                                                                                             | \$17,500,000.00                                   | \$26,250,000.00     | \$31,250,000.00                                                                                              | \$35,000,000.00                                                                                                       |
| Earnings {<br>a. Passenger traffic .<br>b. Freight traffic. . .<br>c. Baggage . . . . .<br>d. Diverse sources. . } | 2,080,000.00                                      | 3,400,000.00        | 4,000,000.00                                                                                                 | 4,800,000.00                                                                                                          |
|                                                                                                                    | Not taken into account.                           |                     |                                                                                                              |                                                                                                                       |
| Total earnings. ....                                                                                               | 2,080,000.00                                      | 3,400,000.00        | 4,000,000.00                                                                                                 | 4,800,000.00                                                                                                          |
| Total operating expenses incl. of<br>reserve fund for repairs. ....                                                | 1,200,000.00                                      | 200,000.00          | 2,425,000.00                                                                                                 | 2,950,000.00                                                                                                          |
| Surplus of earnings over ex-<br>penses. ....                                                                       | 880,000.00                                        | 1,400,000.00        | 1,575,000.00                                                                                                 | 1,850,000.00                                                                                                          |
| Sinking fund ( $\frac{1}{2}\%$ of the cap-<br>ital). ....                                                          | 87,500.00                                         | 106,250.00          | 156,125.00                                                                                                   | 175,000.00                                                                                                            |
| Net profits. ....                                                                                                  | 792,500.00                                        | 1,268,750.00        | 1,418,750.00                                                                                                 | 1,675,000.00                                                                                                          |
| Reserve fund (5% of net profits).                                                                                  | 40,000.00                                         | 63,750.00           | 71,250.00                                                                                                    | 85,000.00                                                                                                             |
| Balance available for paying in-<br>terest on the capital. ....                                                    | 752,500.00                                        | 1,205,000.00        | 1,347,500.00                                                                                                 | 1,590,000.00                                                                                                          |
| Interest in per cent of the cap-<br>ital. ....                                                                     | 4.3%                                              | 4.6%                | 4.3%                                                                                                         | 4.6%                                                                                                                  |



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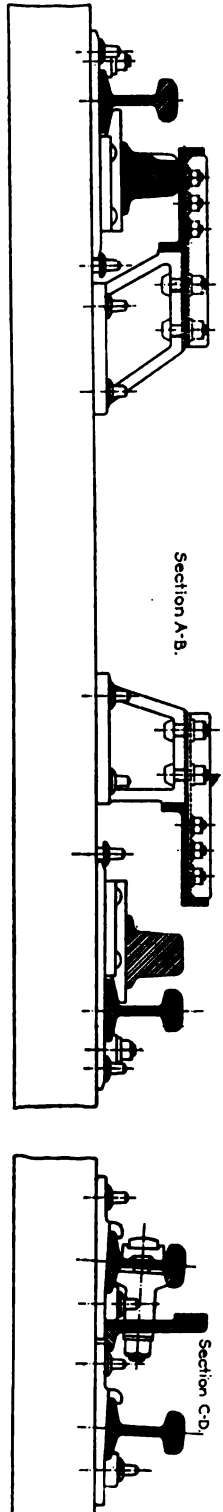


PLATE I.—Arrangement of the Guard-rails at the Switch-point.



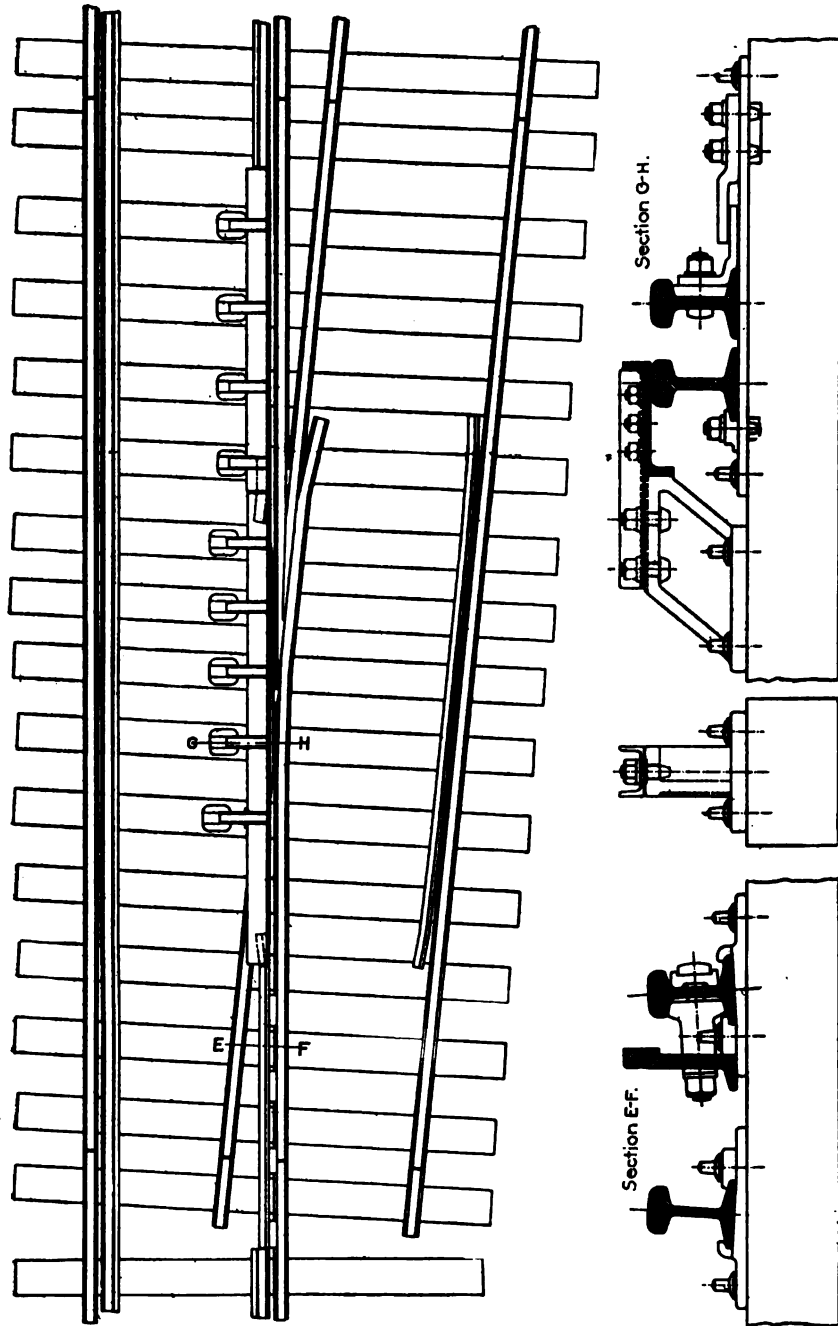
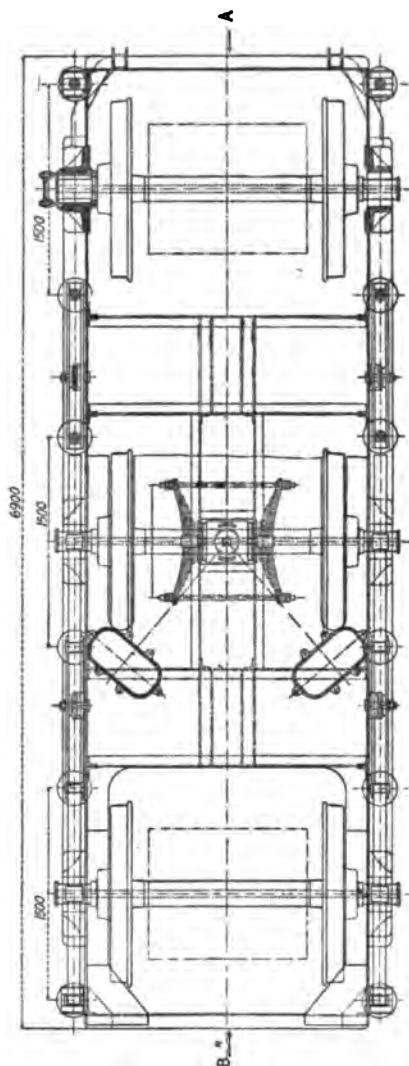
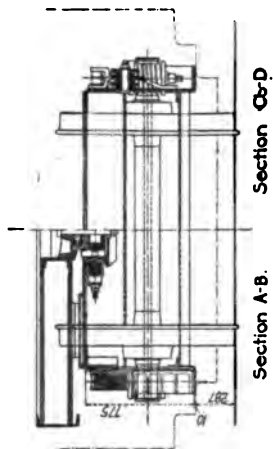
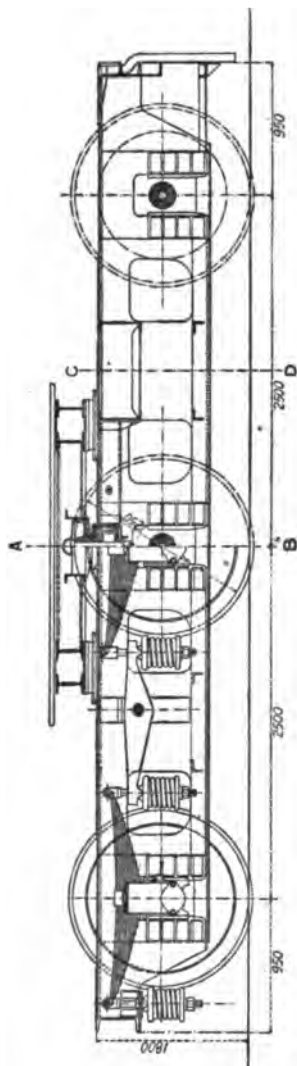


PLATE II.—Arrangement of the Guard-rails at the Frog of the Switch.



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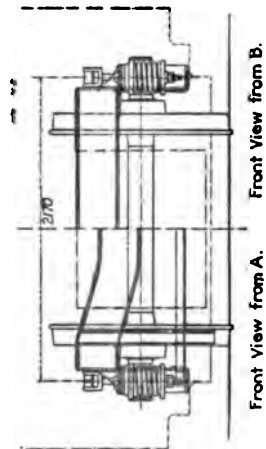


PLATE III.—Swivel Truck. Numbers indicate millimeters.

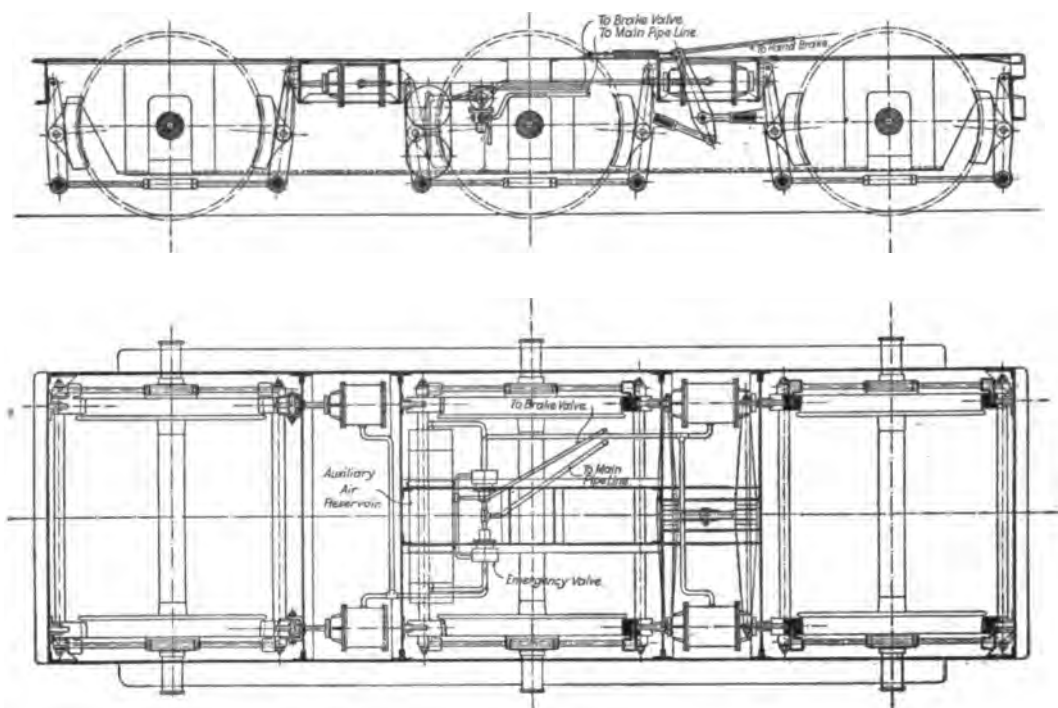


PLATE IV.—Arrangement of the Brake.

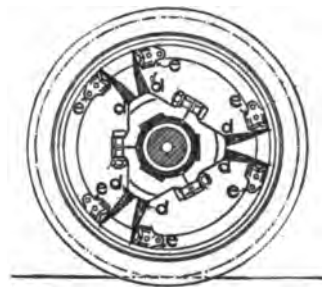
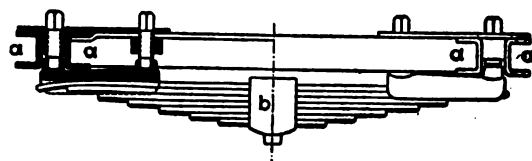
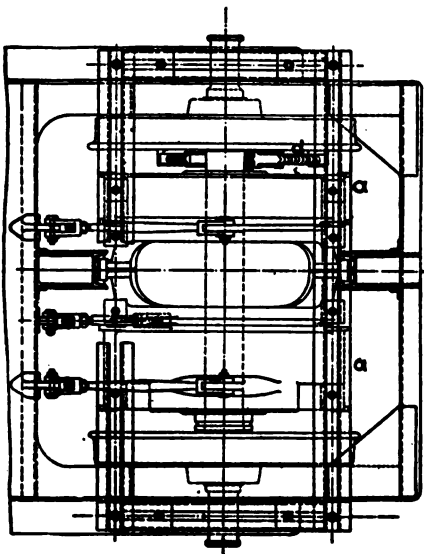
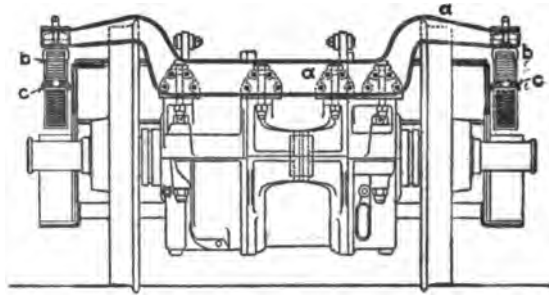
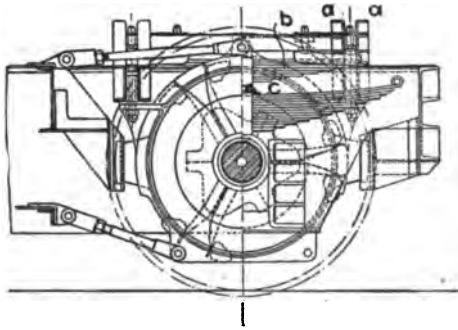


PLATE V.—Method of Suspending the Motors. Car "A."

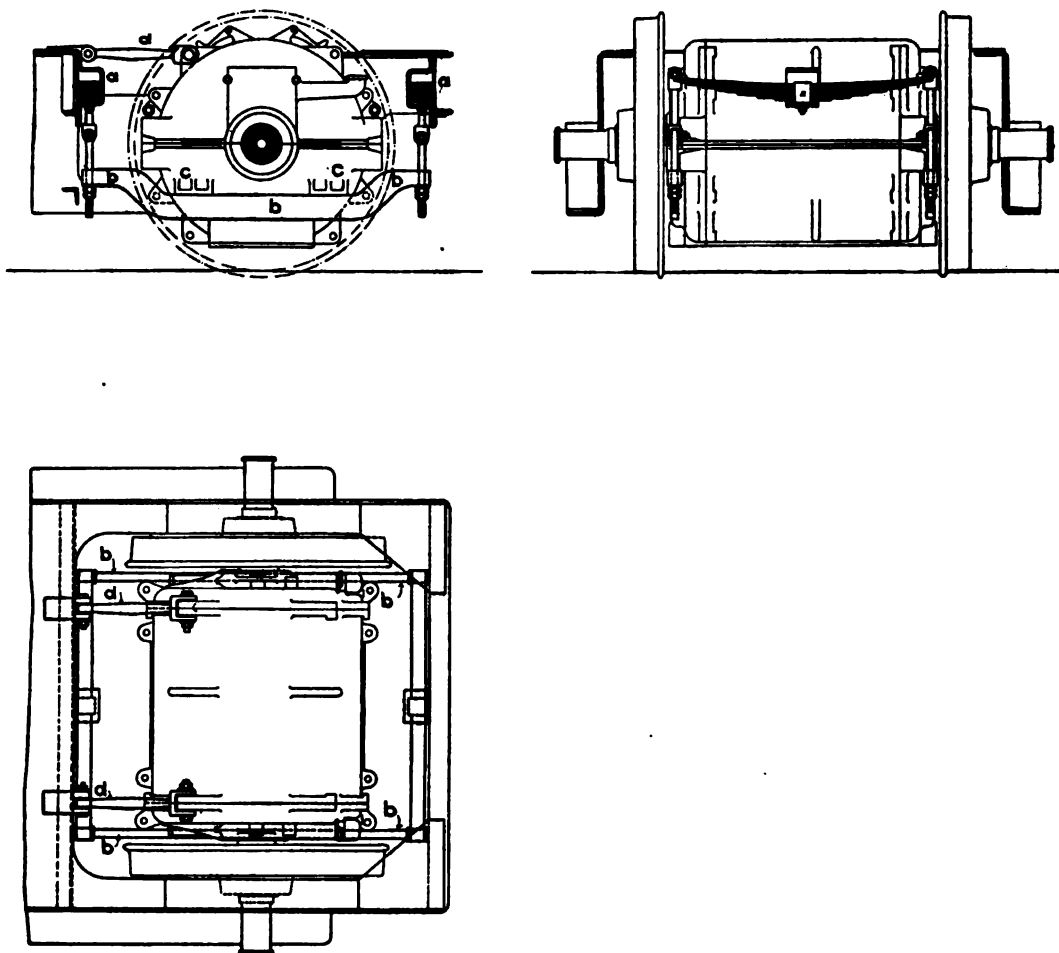


PLATE VI.—Method of Suspending the Motors. Car "S."

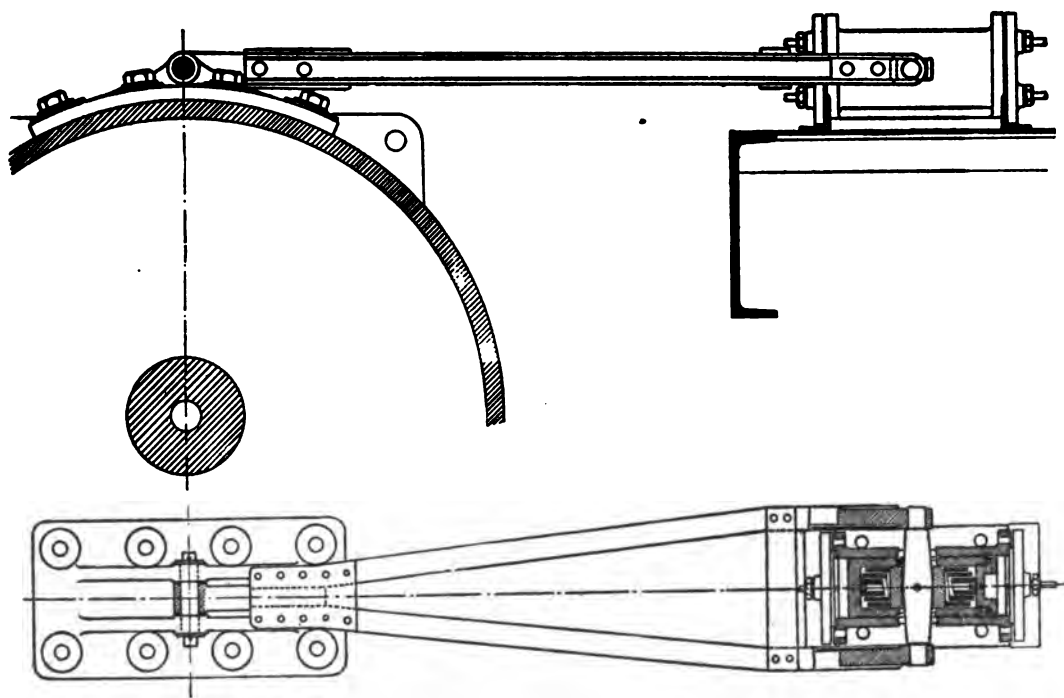


PLATE VII.—Device for Measuring the Torque.

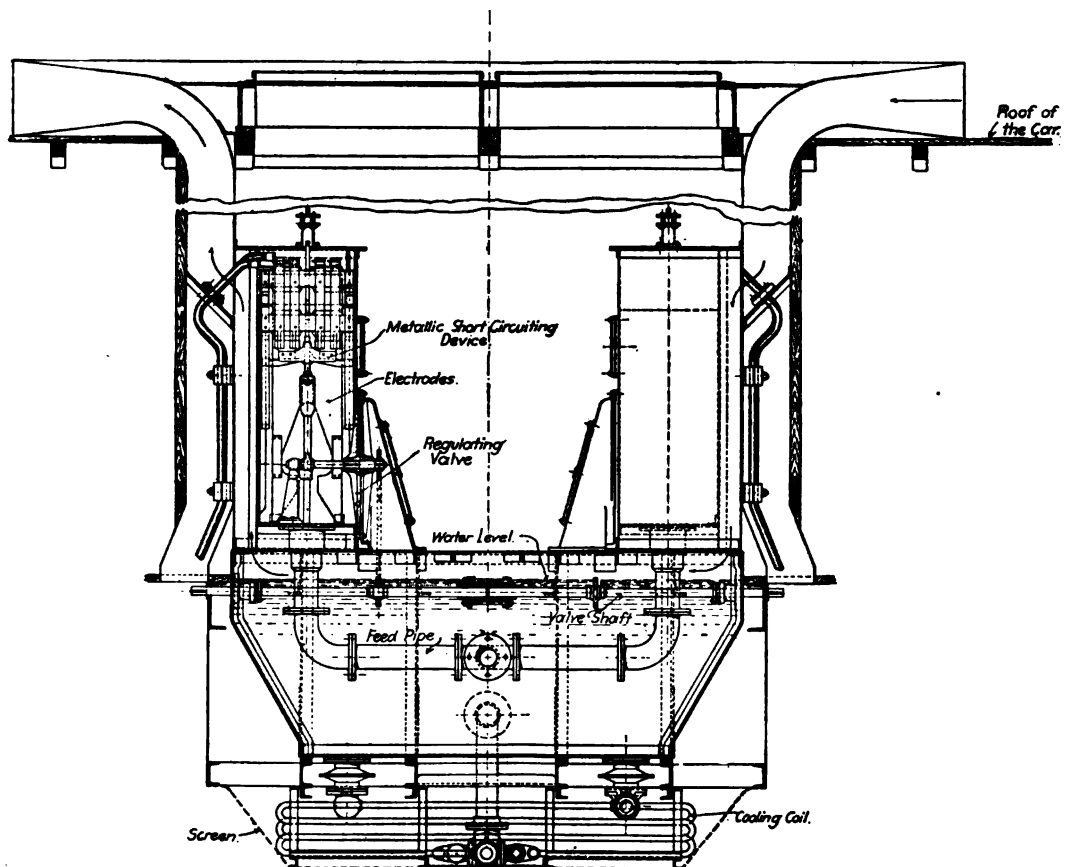


PLATE VIII.—Water Rheostat.  
(See next page.)

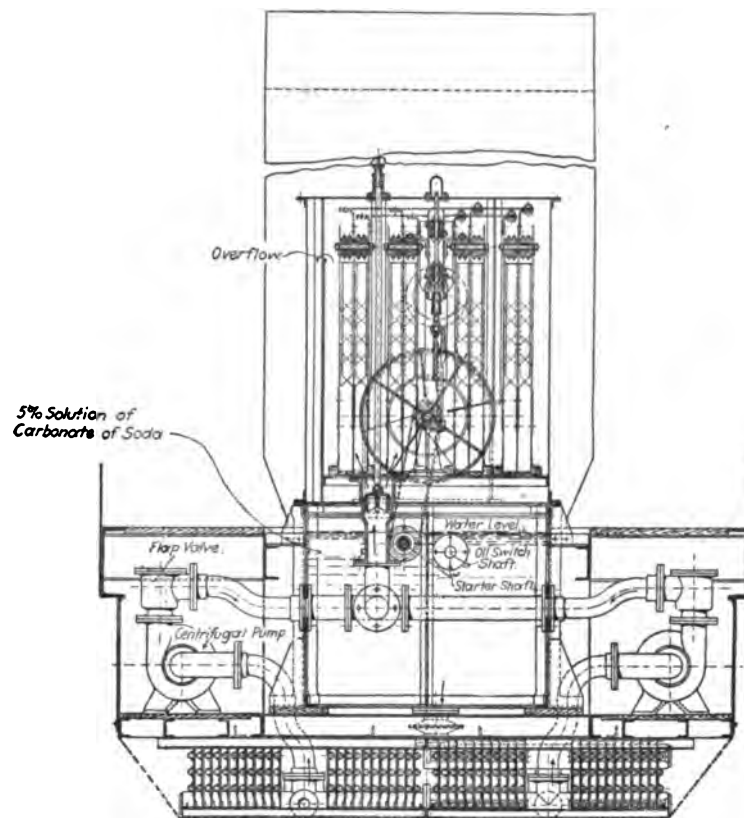


PLATE VIIIa.—Water Rheostat.  
(See previous page.)



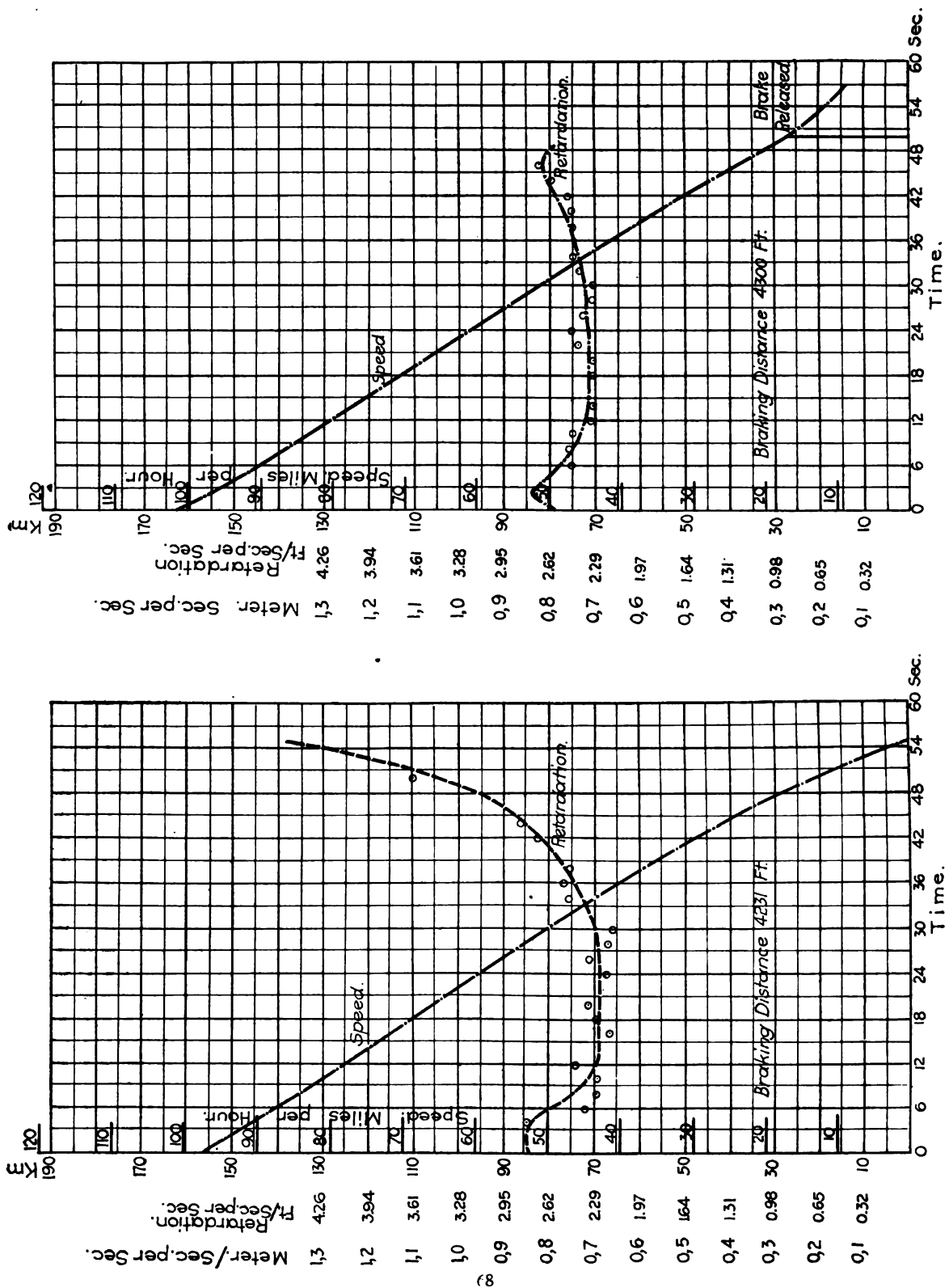


PLATE IX.—Brake Tests on Car "A."

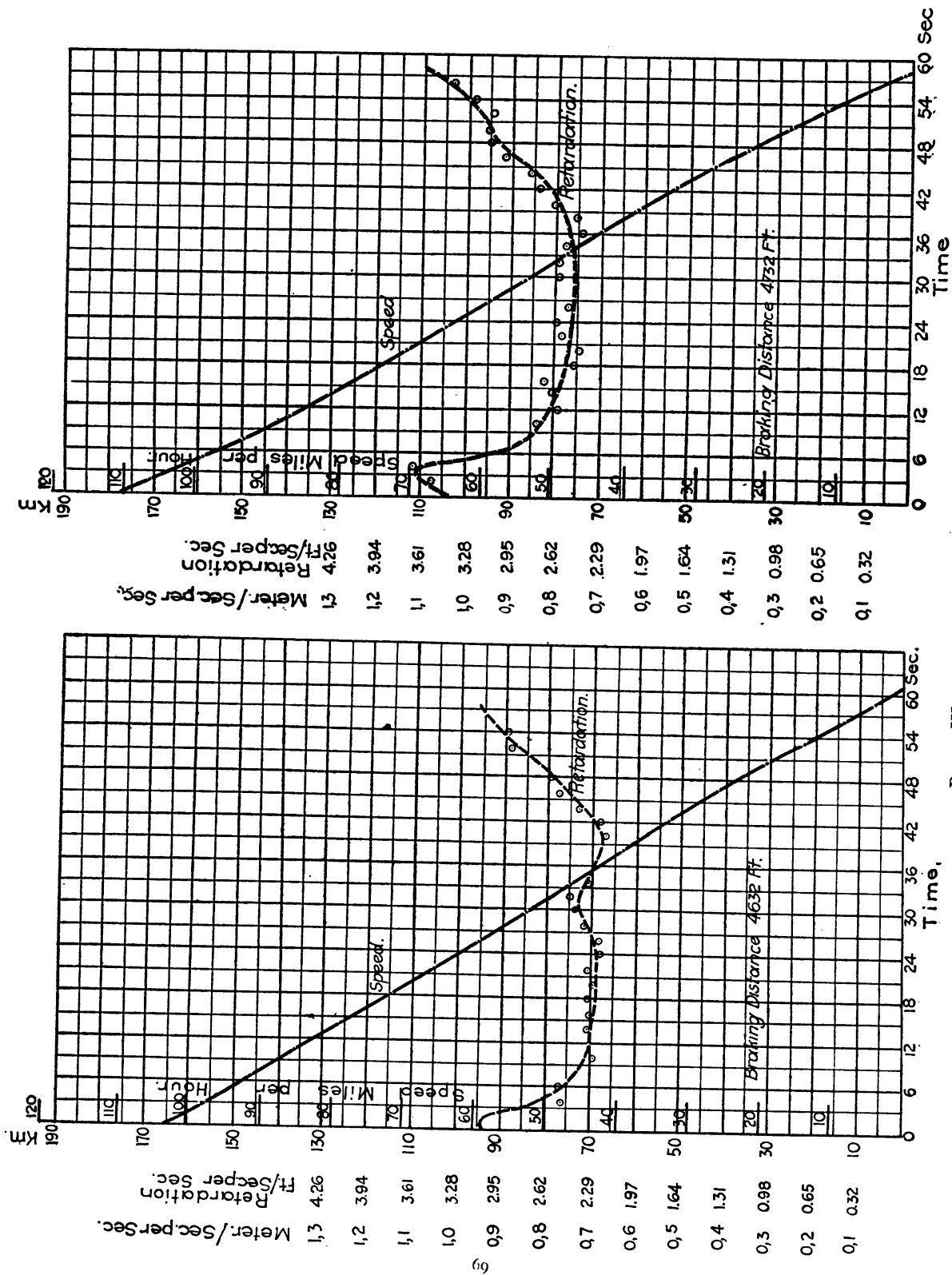


PLATE IXa.—Brake Tests on Car "A."

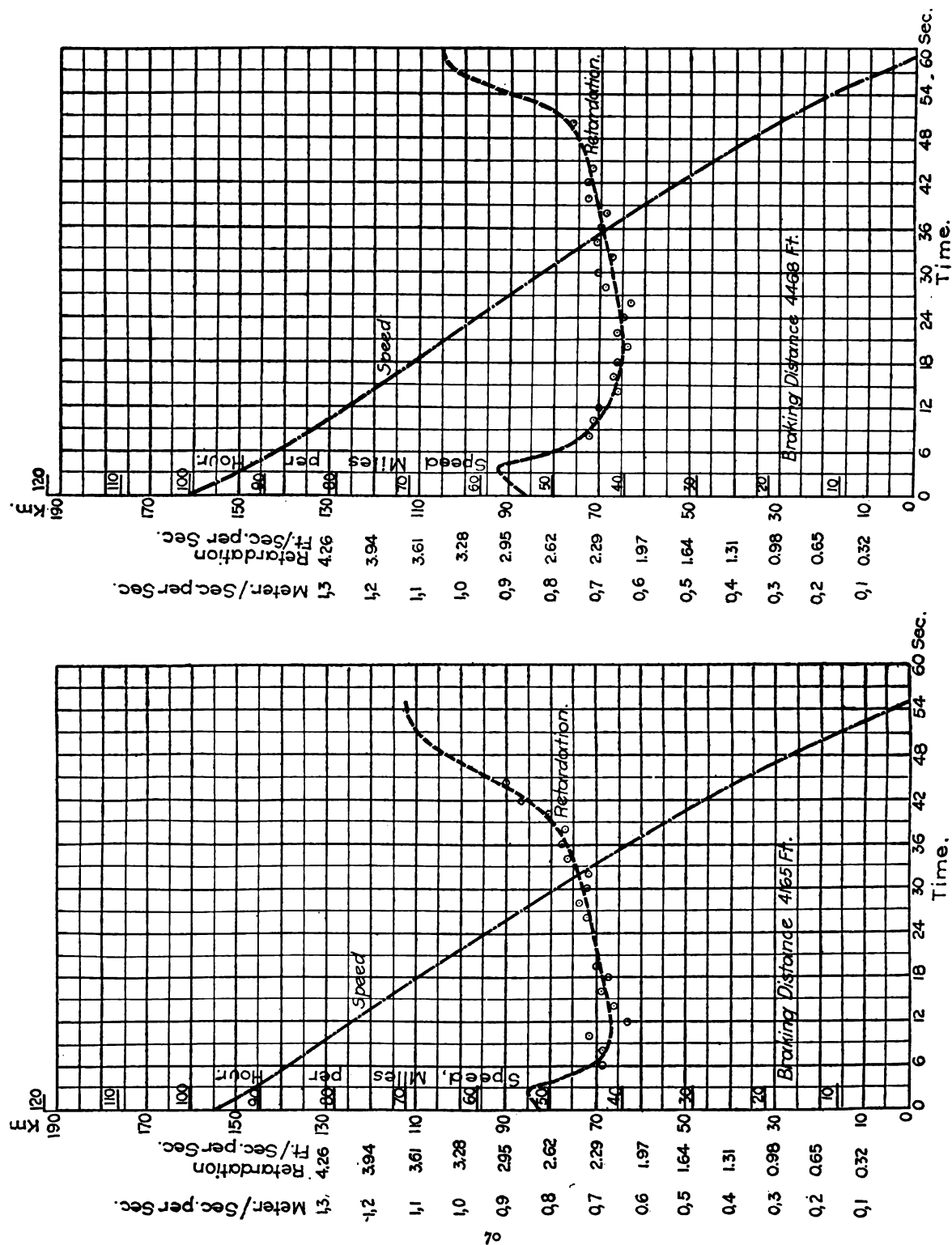


PLATE X.—Brake Tests with Car 'S.'

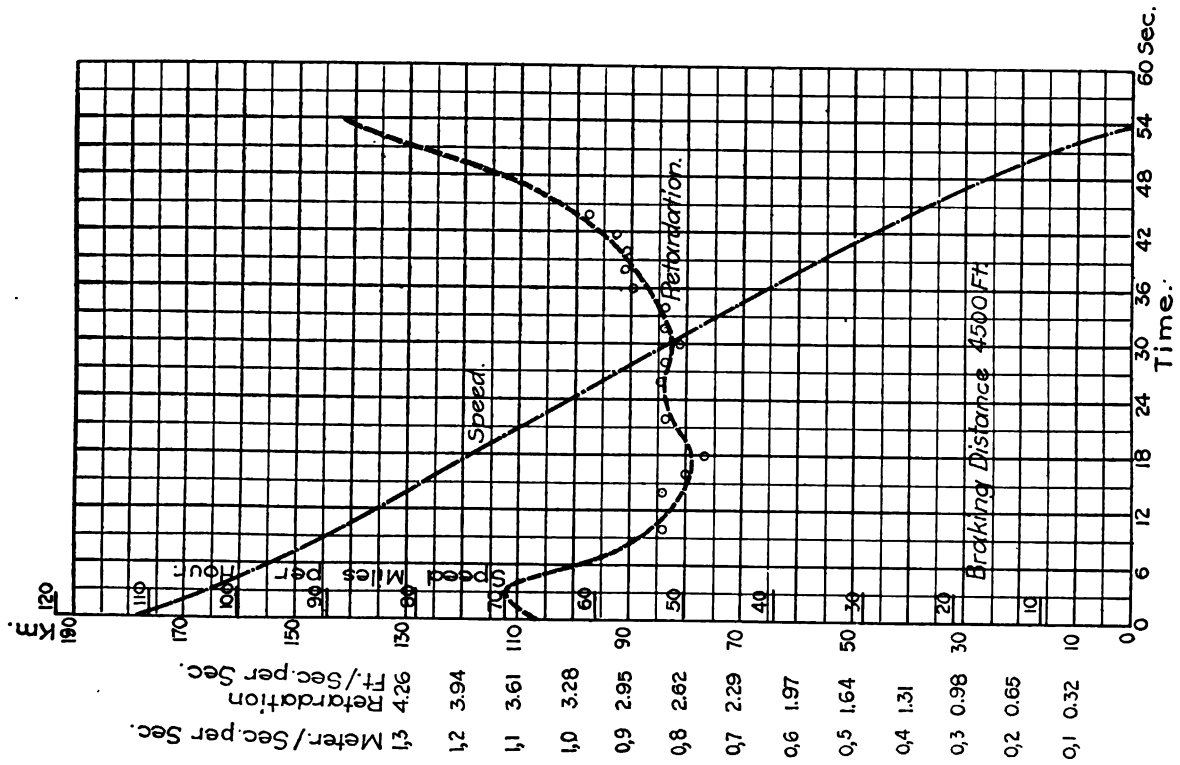
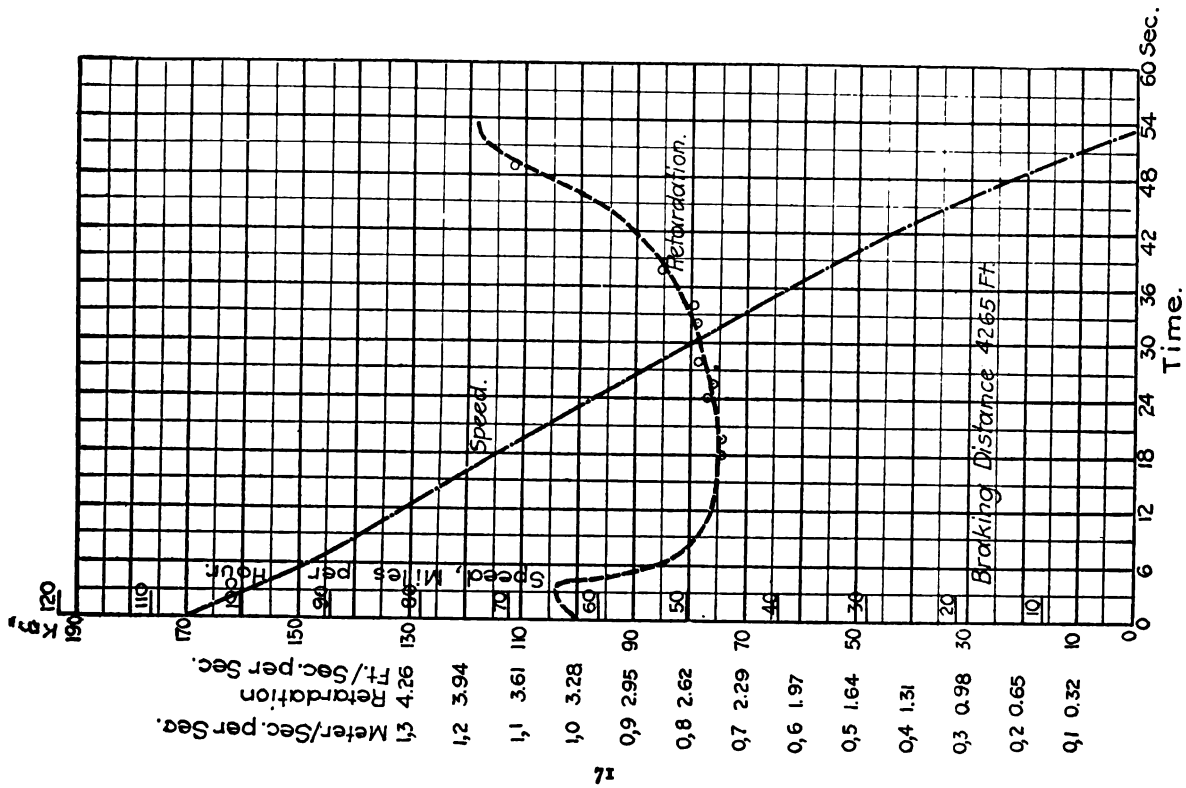


PLATE Xa.—Brake Tests with Car "S."

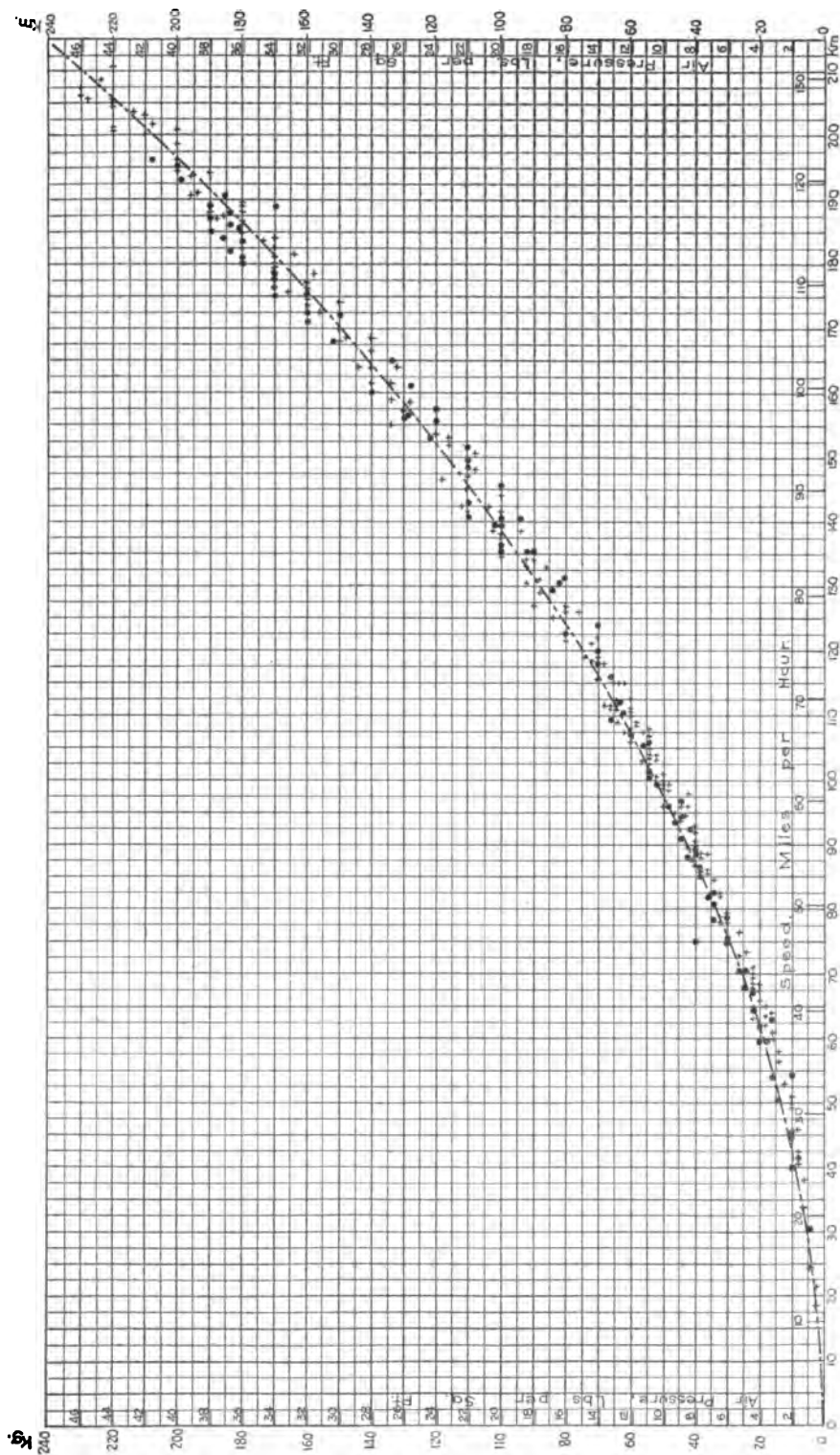


PLATE XI.—Air-pressure Measurements.



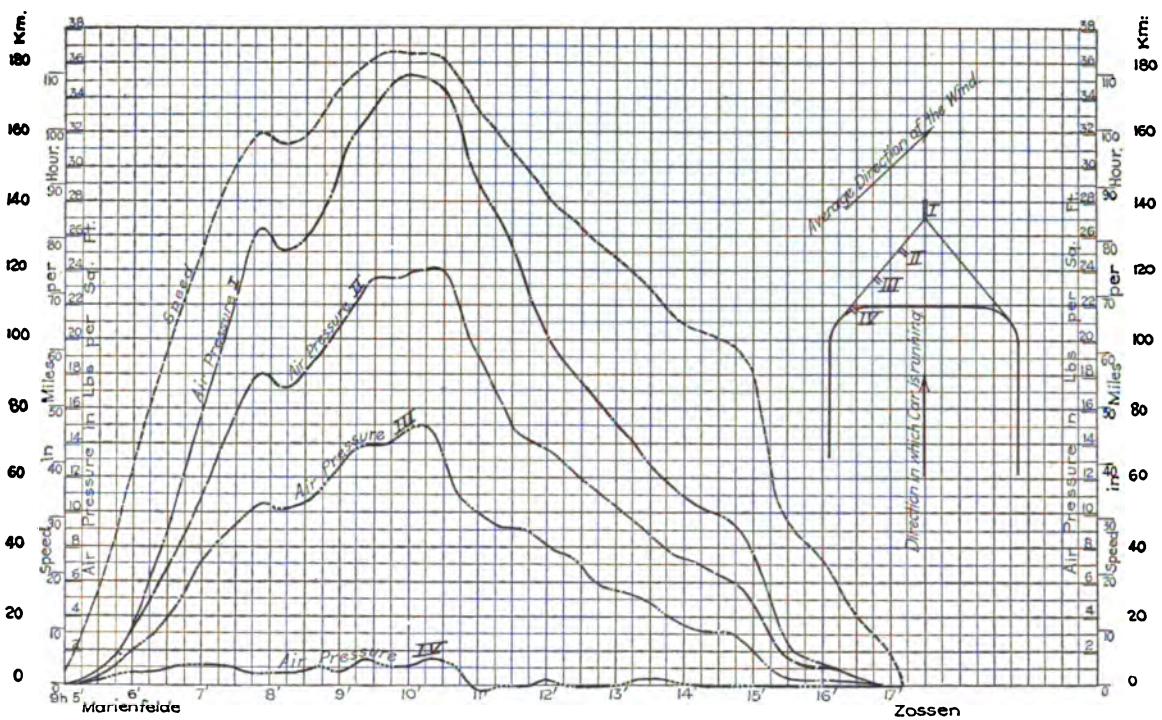


PLATE XII.—Air-pressure Measurements. Car "A."

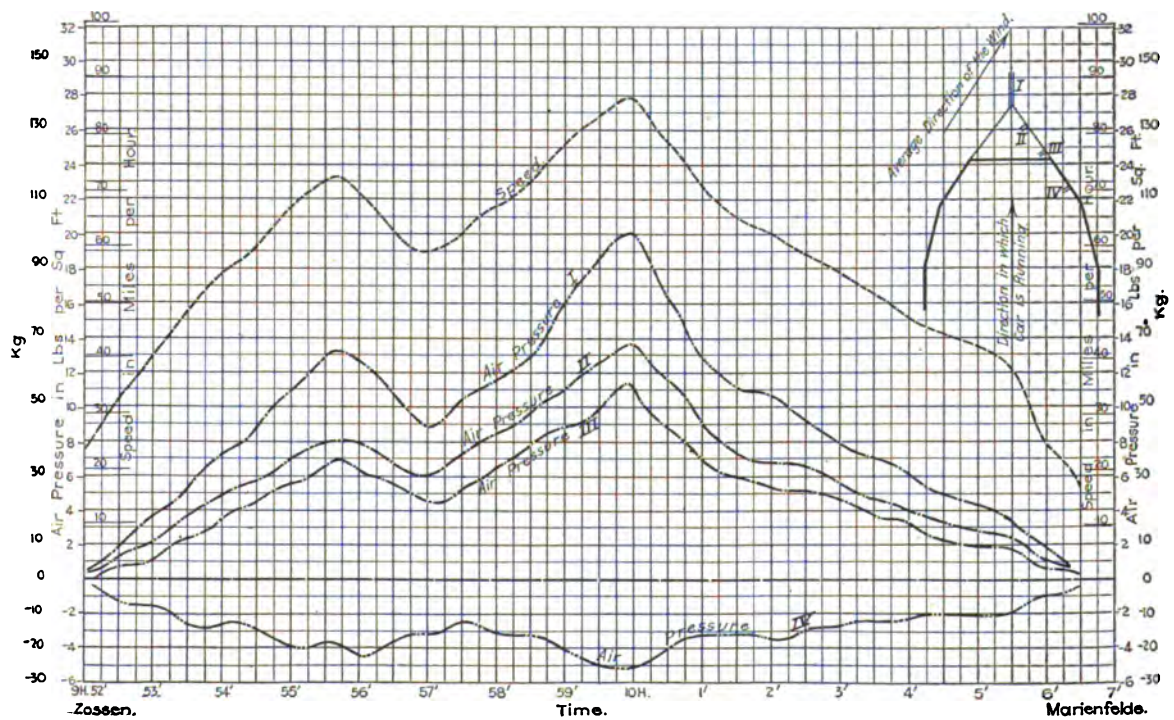


PLATE XIII.—Air-pressure Measurements. Car "S."

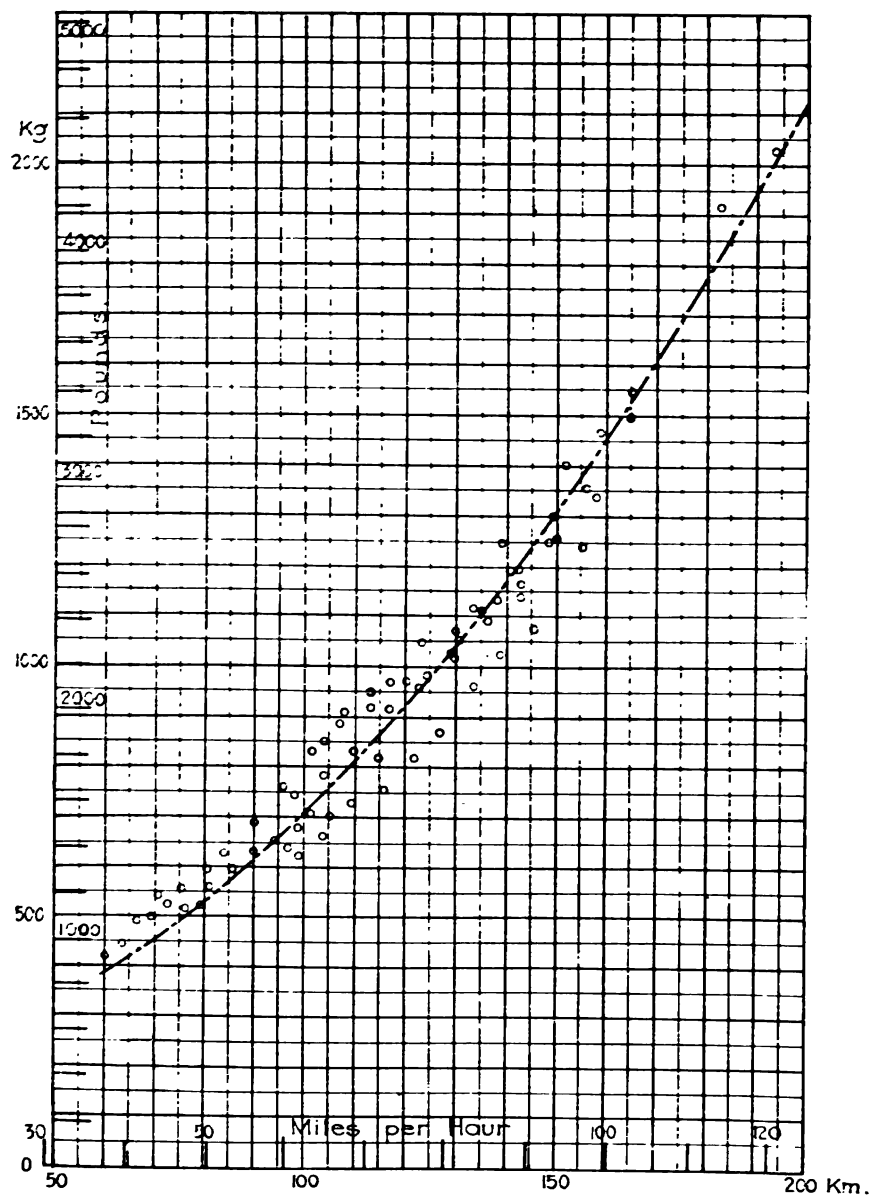


PLATE XIV.—Train Resistance of Car "A," with Detachable Noses, as found from the Tests made in the Fall of 1903.

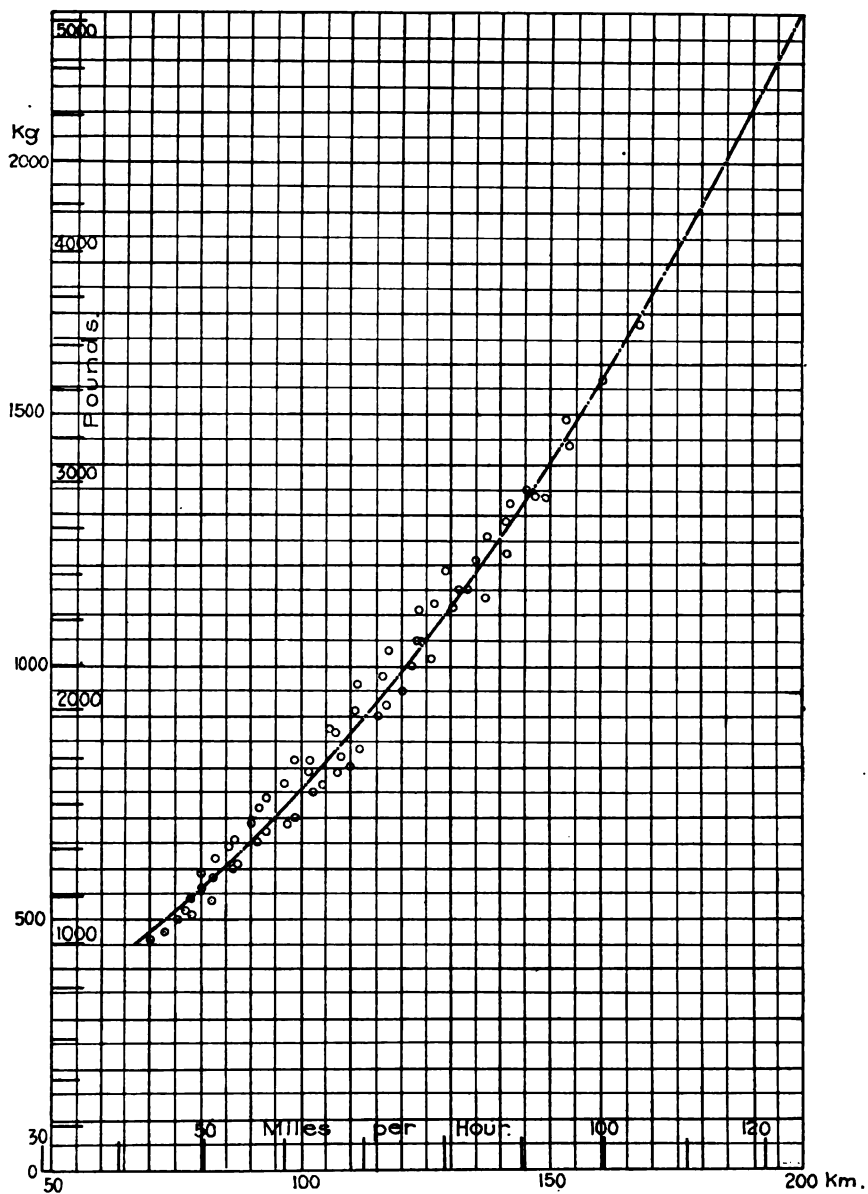


PLATE XIVa.—Train Resistance of Car "A," without Detachable Nose, as found from the Tests made in the Fall of 1903.



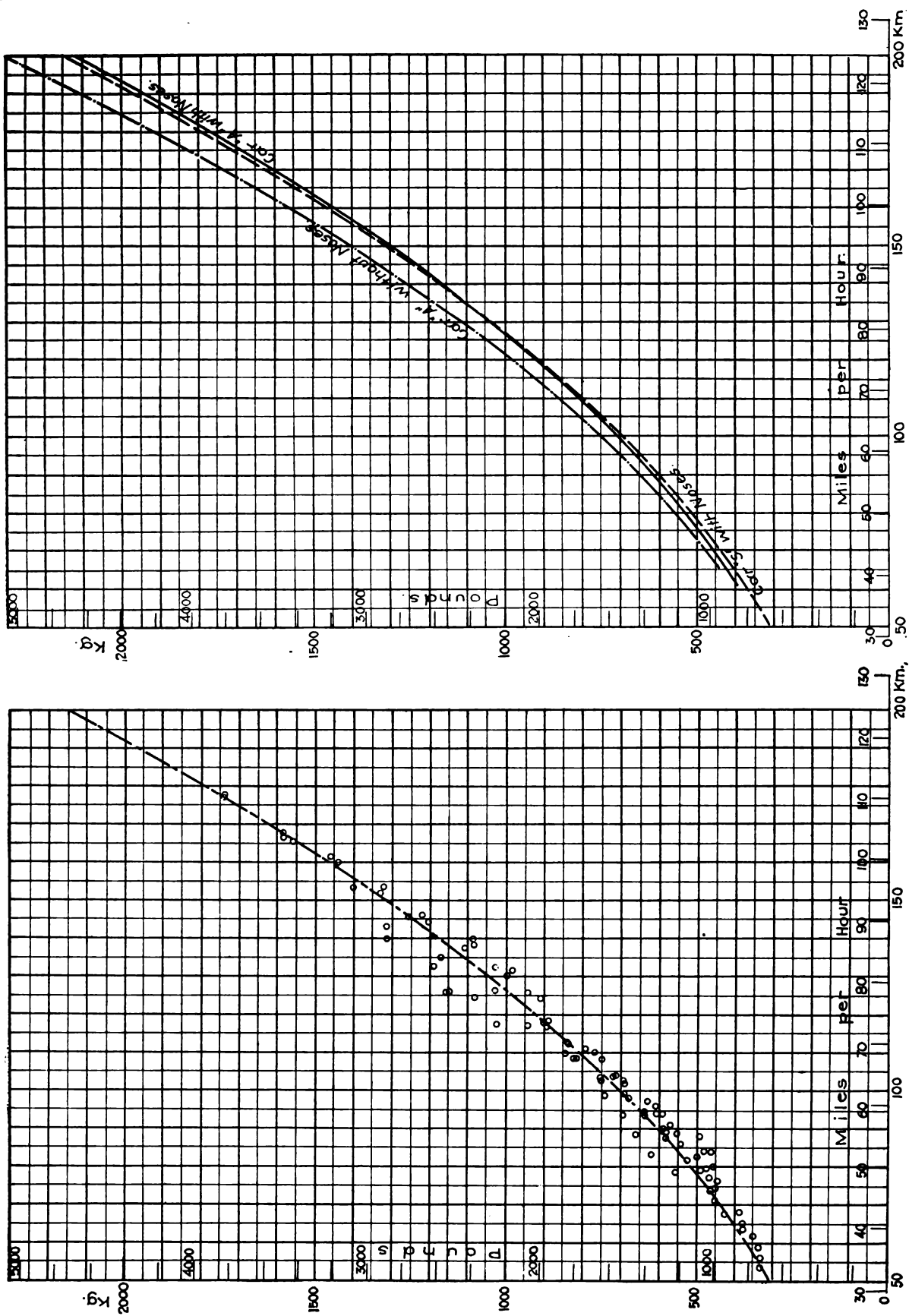


PLATE XV.—Train Resistance of Cars with Detachable Noses, as found from the Tests made in the Fall of 1903.

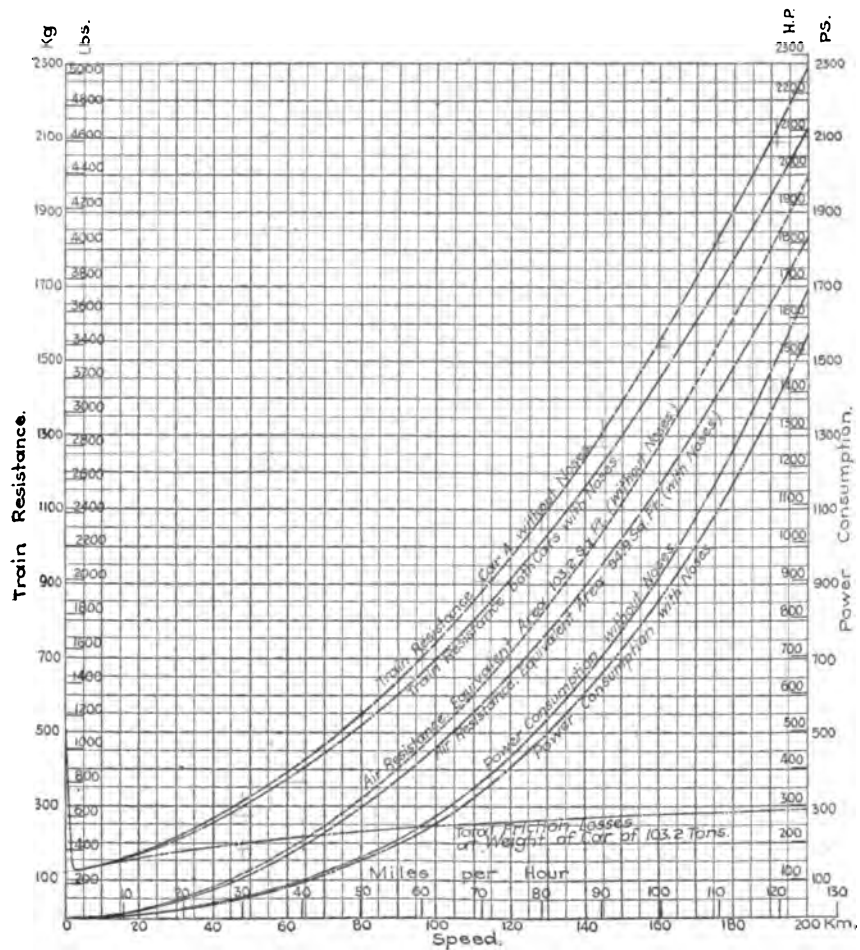


PLATE XVa.—Train Resistance and Power Consumption of the High-speed Cars, as found from the Tests made in the Fall of 1902 and 1903.

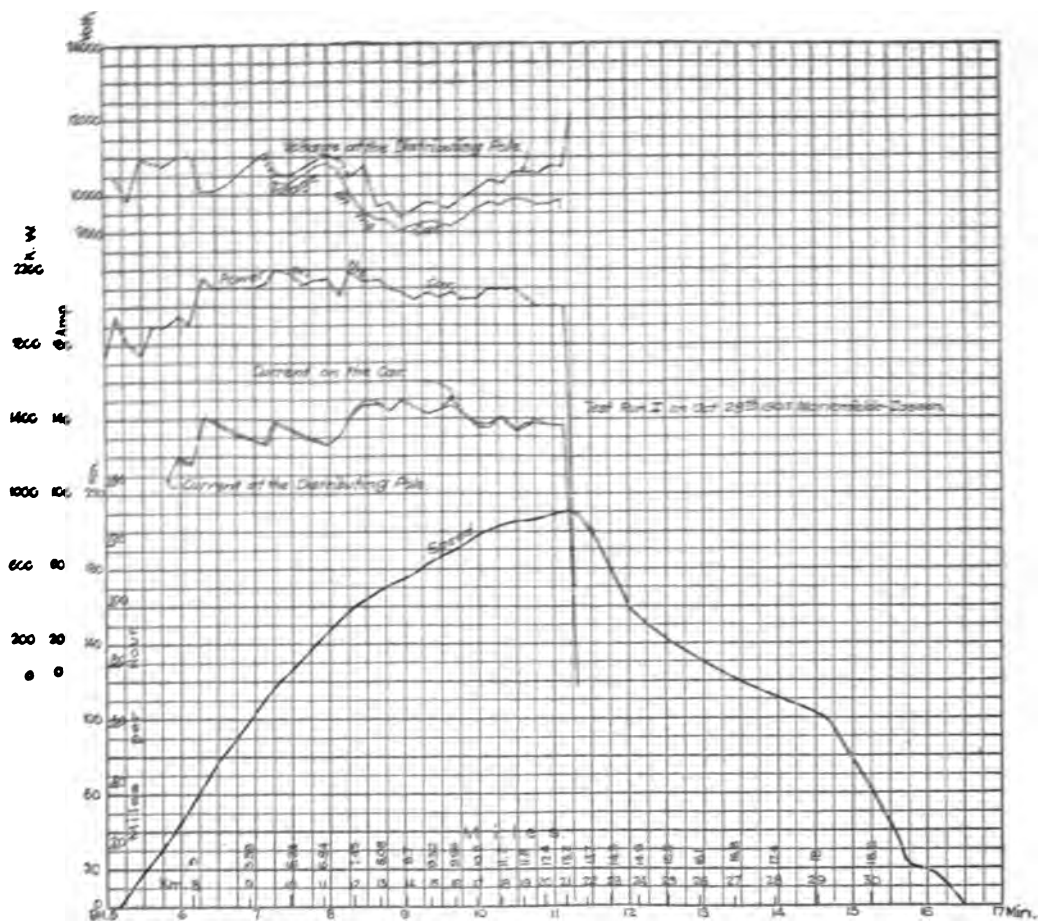


PLATE XVI.—Test Runs with Car "A." Speed, Current, Voltage, Power.

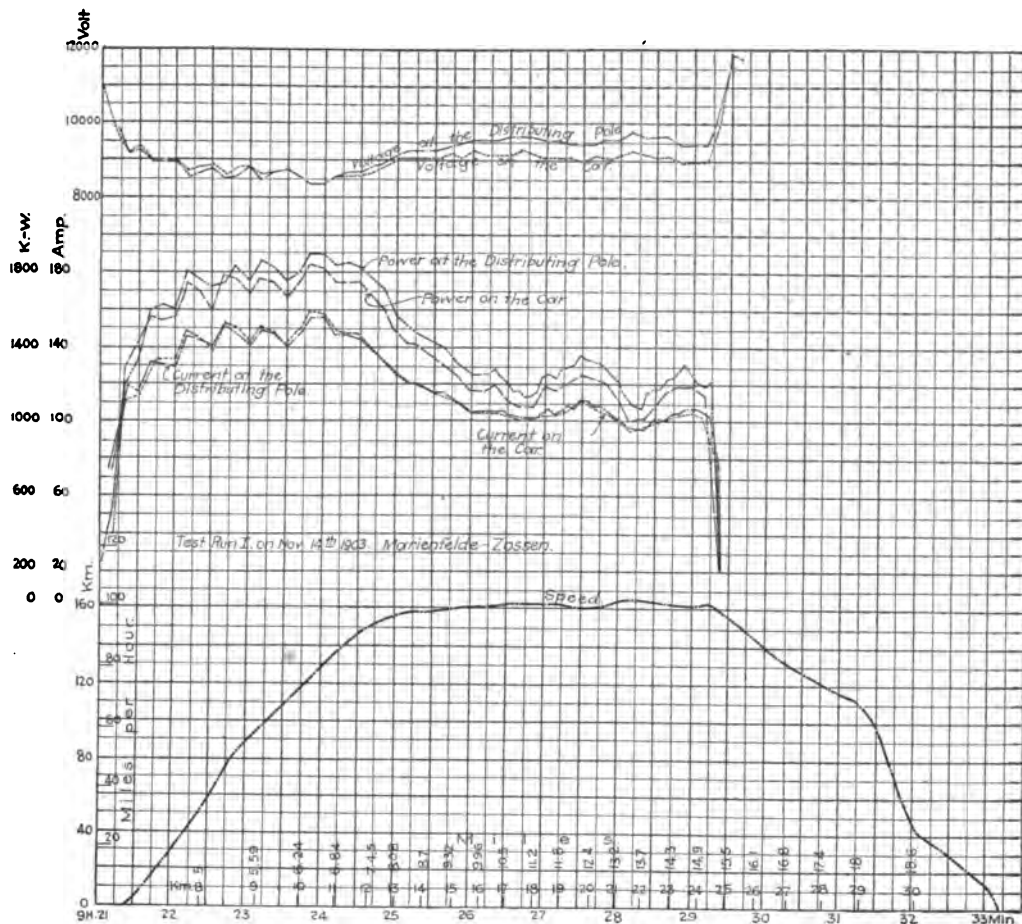


PLATE XVII.—Test Runs with Car "A." Speed, Current, Voltage, Power.

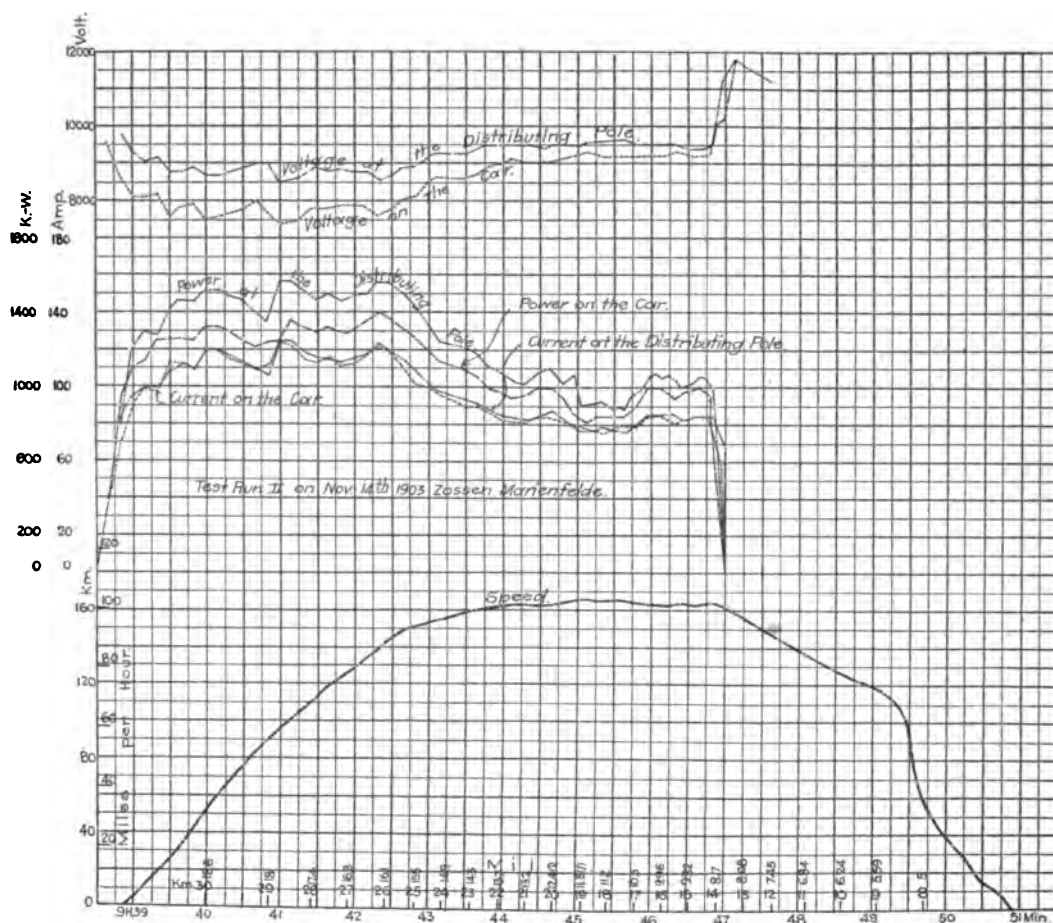


PLATE XVIII.—Test Runs with Car "A." Speed, Current, Voltage, Power.

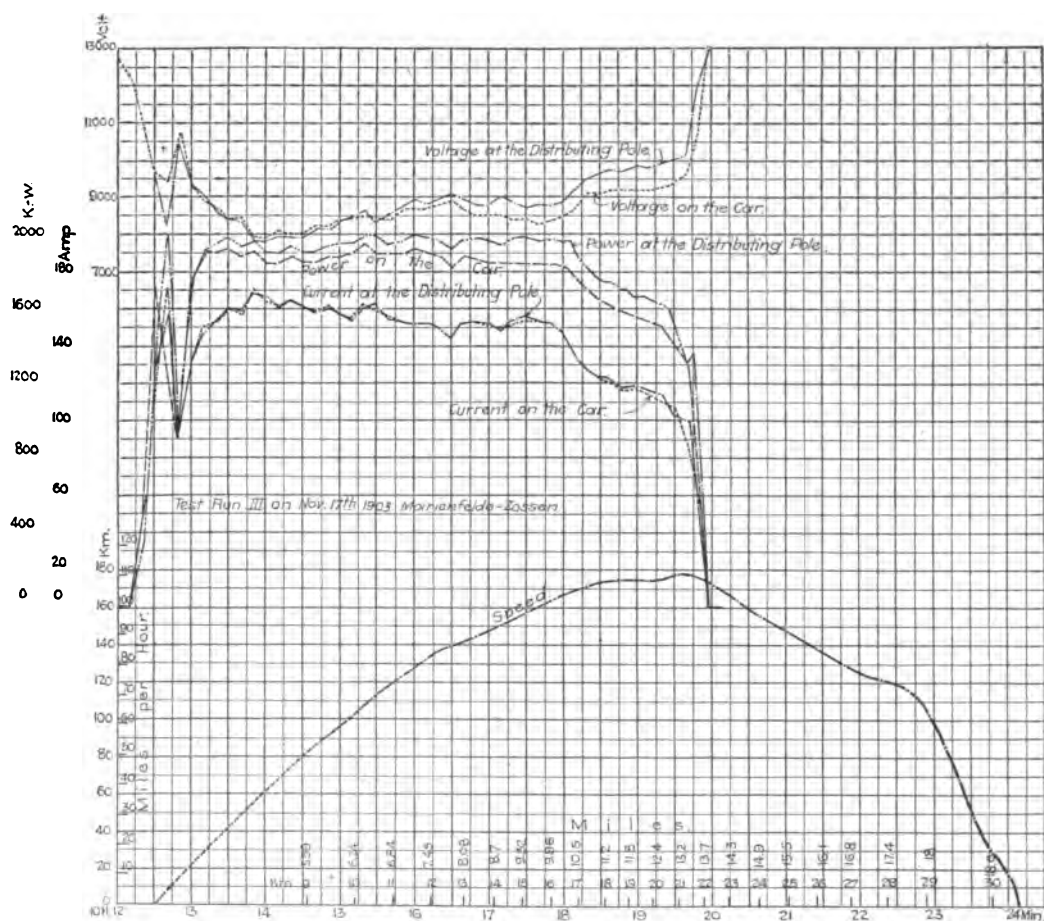


PLATE XIX.—Test Runs with Car "A," and Six-wheel Double-truck Sleeper. Total Weight of Train 304,260 lbs. Speed, Current, Voltage, Power.

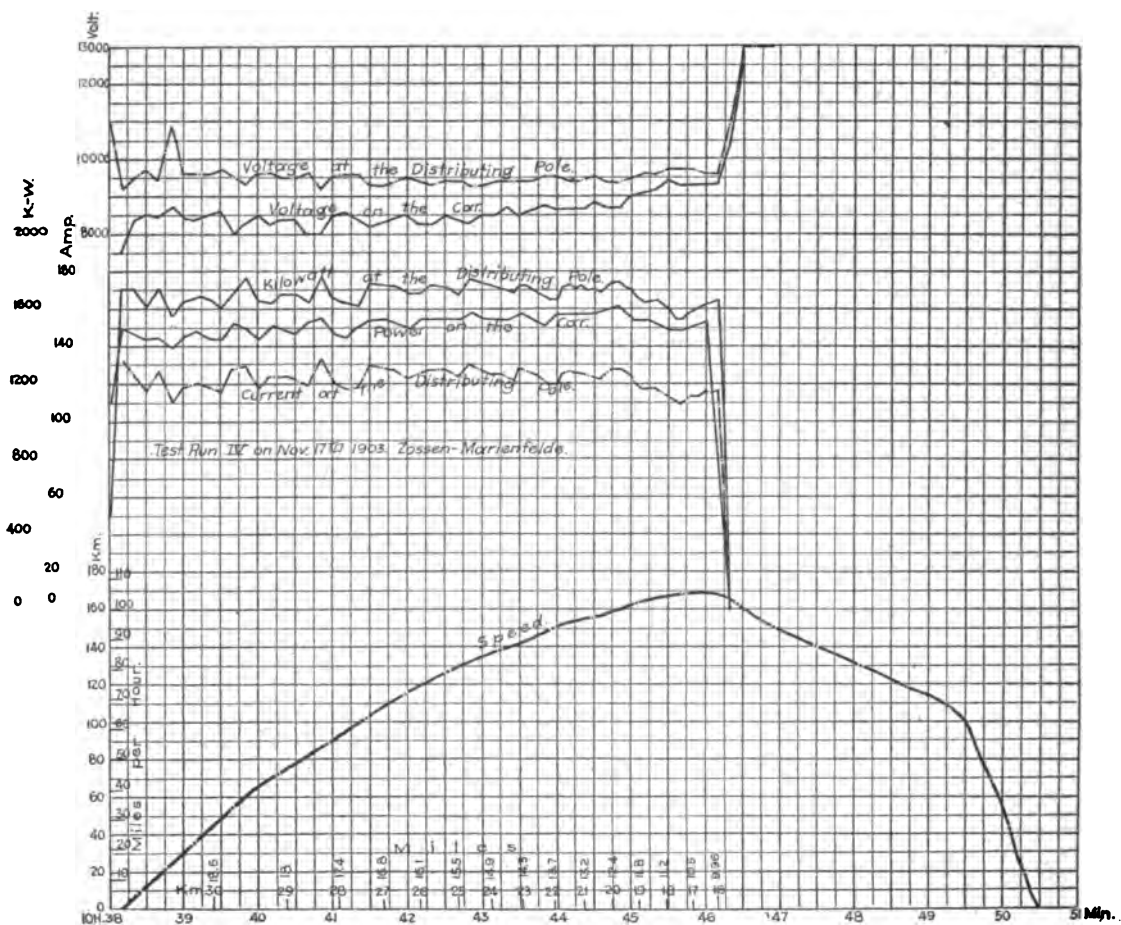


PLATE XX.—Test Runs with Car "A" and Six-wheel Double-truck Sleeper. Total Weight of Train, 304,260 lbs. Speed, Current, Voltage, Power.

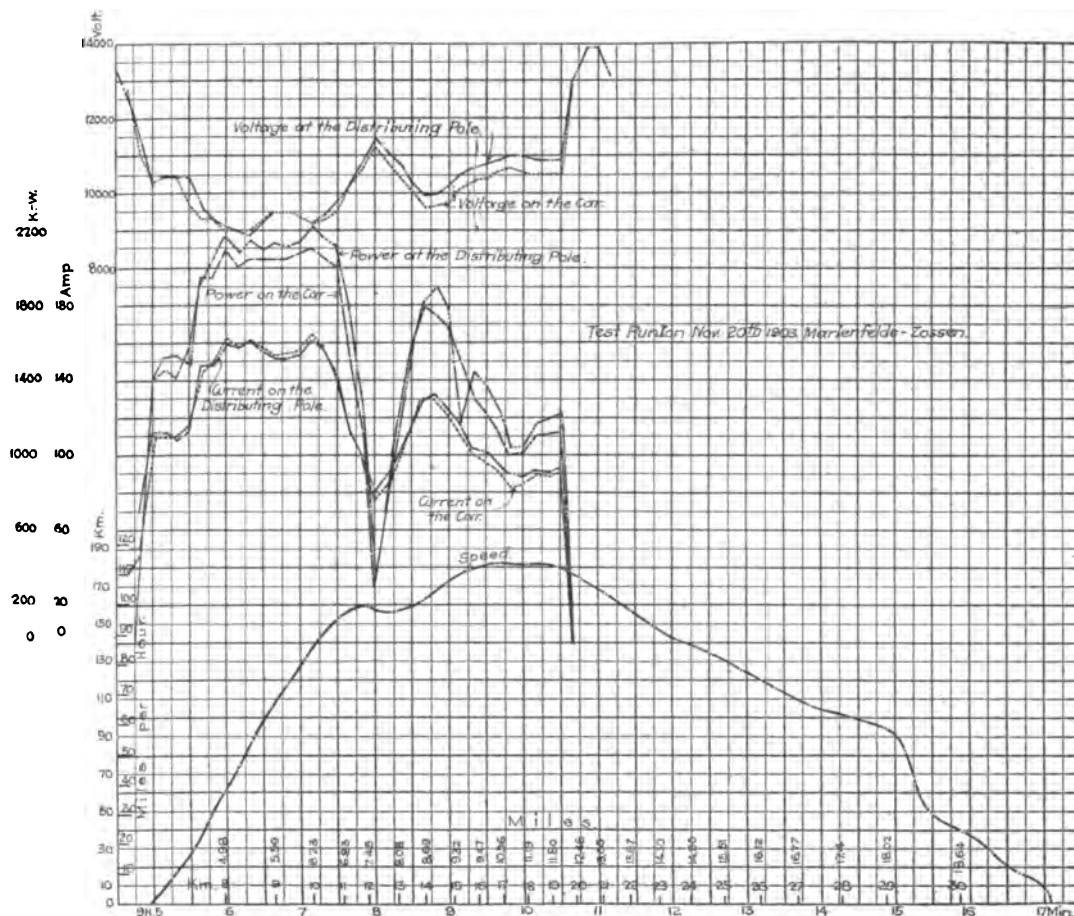


PLATE XXI.—Test Runs with Car "A" with Detachable Nose. Speed, Current, Voltage, Power.



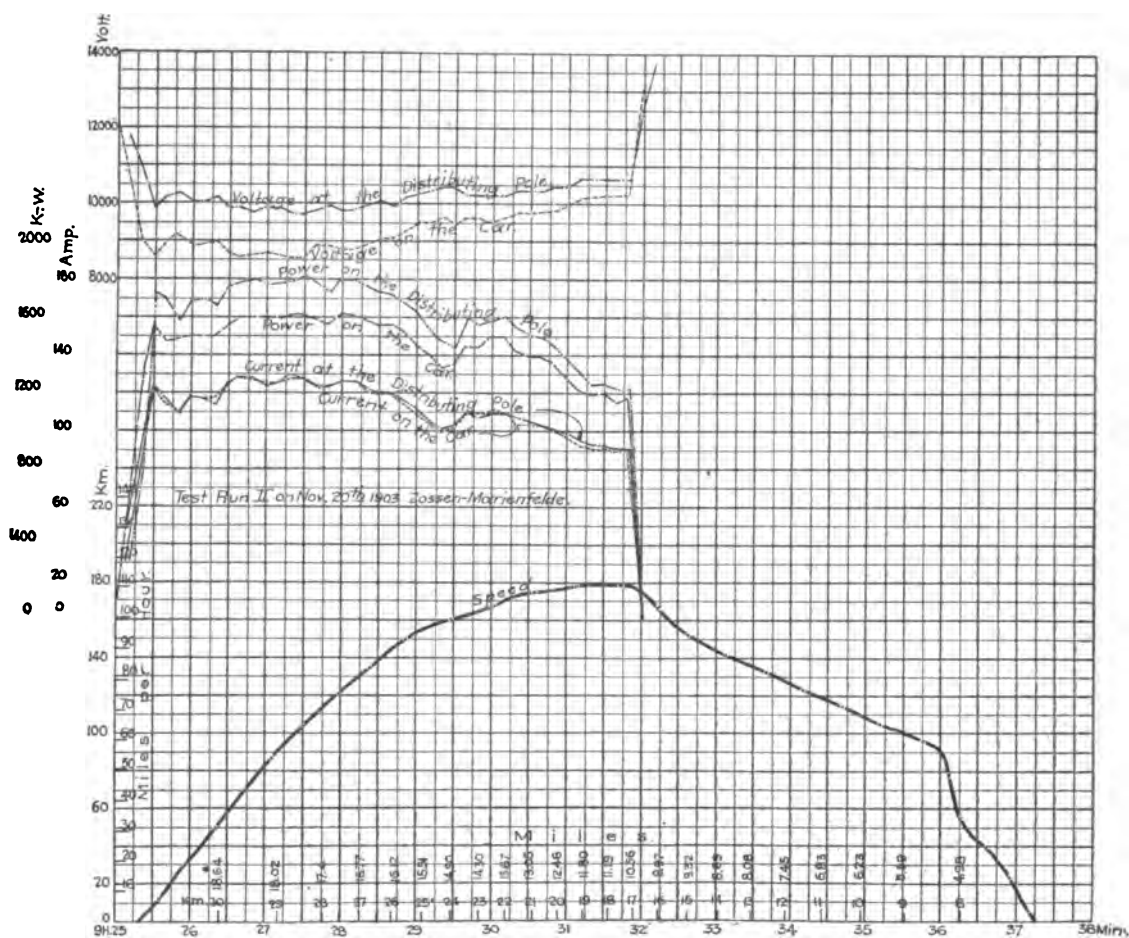


PLATE XXII.—Test Run with Car "A" with Detachable Nose. Speed, Current, Voltage, Power.

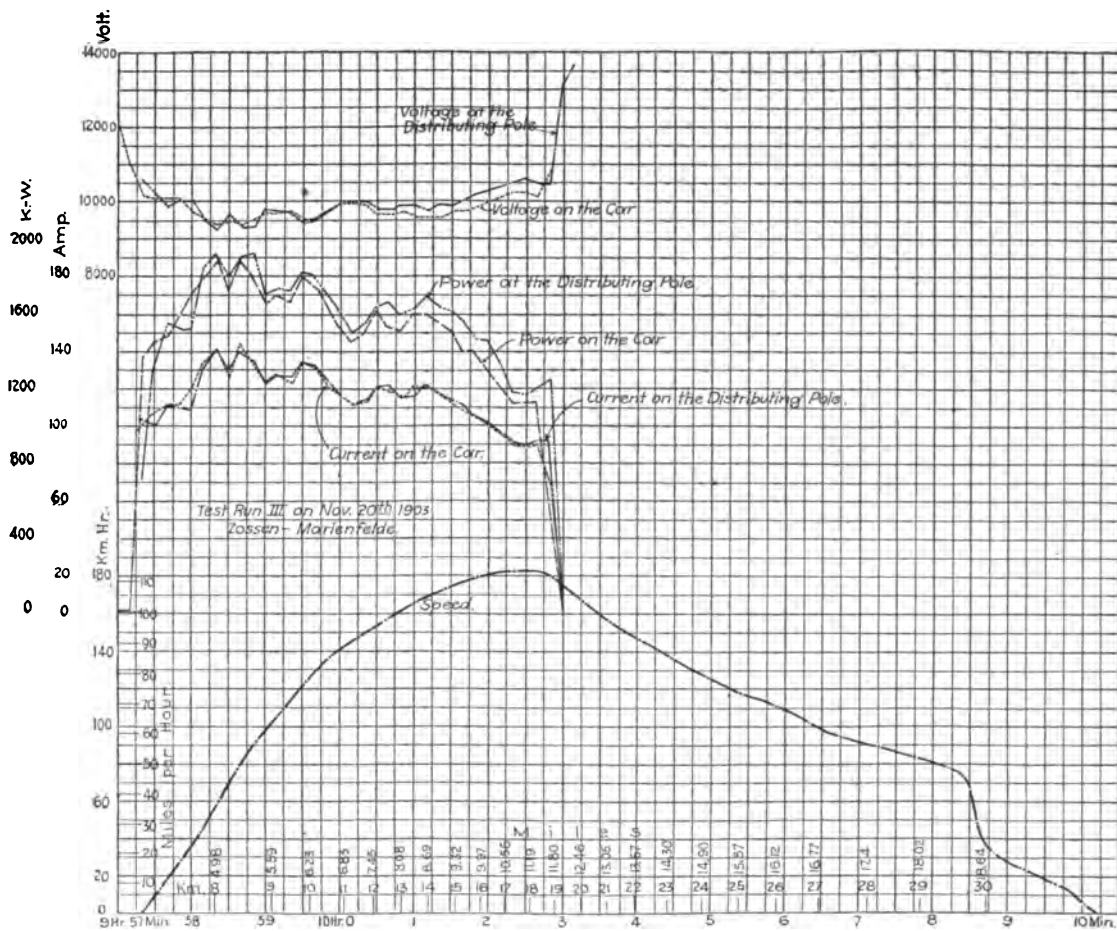


PLATE XXIII.—Test Runs with Car "A," without Detachable Nose. Speed, Current, Voltage, Power.

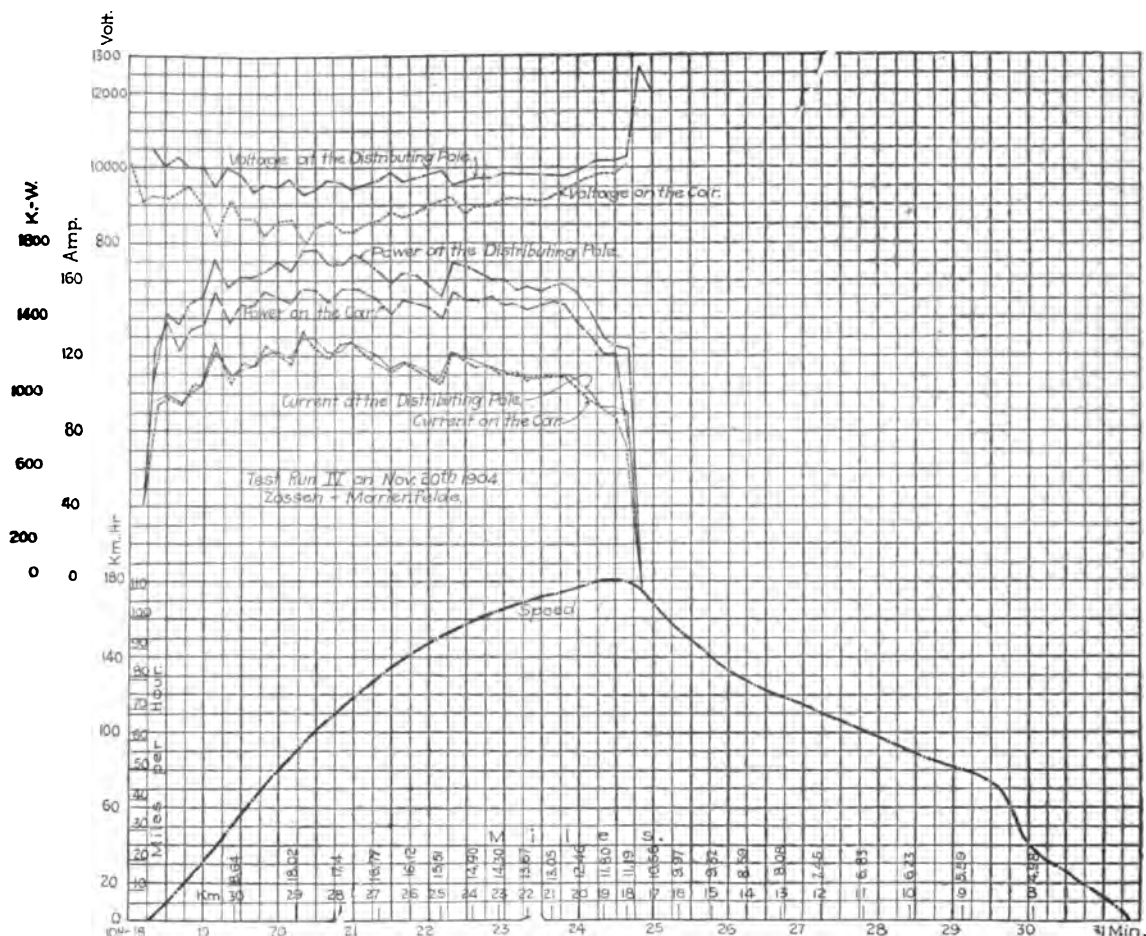


PLATE XXIV.—Test Runs with Car "A," without Nose. Speed, Current, Voltage, Power.

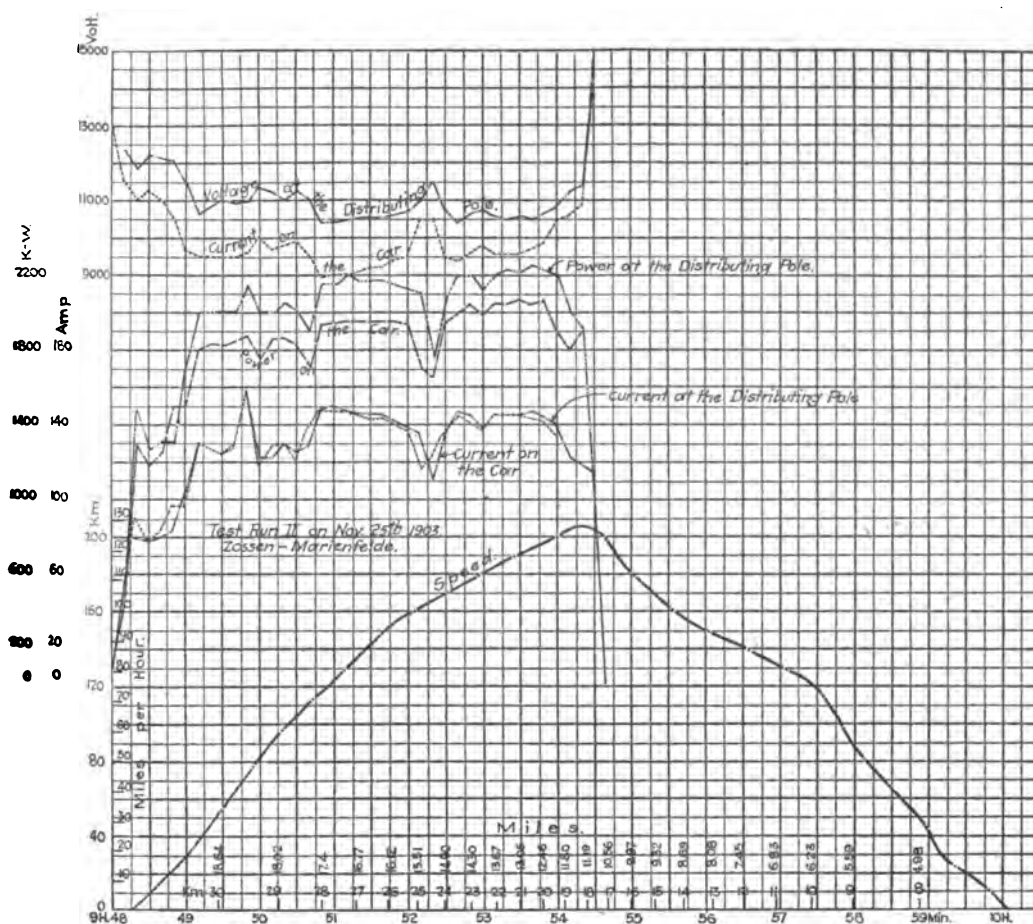


PLATE XXV.—Test Runs with Car "A." Speed, Current, Voltage, Power.

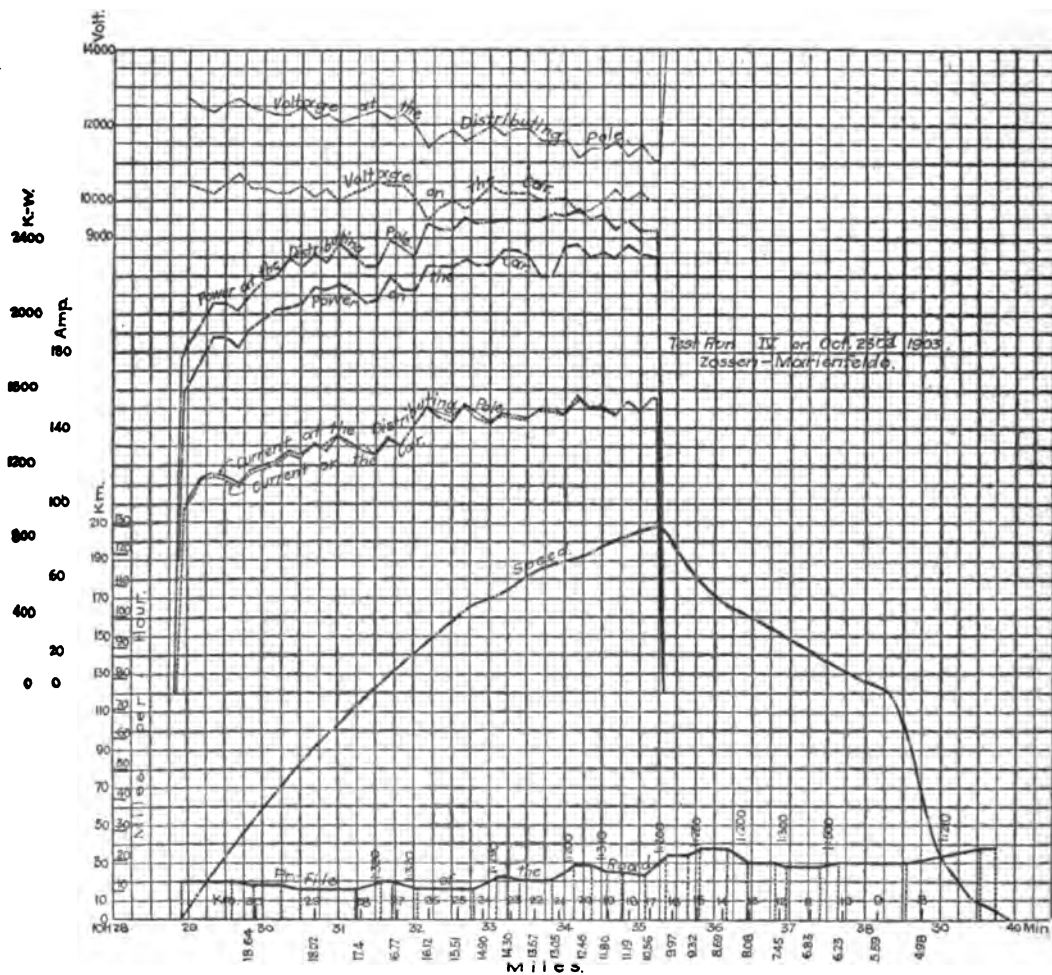


PLATE XXVI.—Test Run with Car "S." Speed, Current, Voltage, Power.

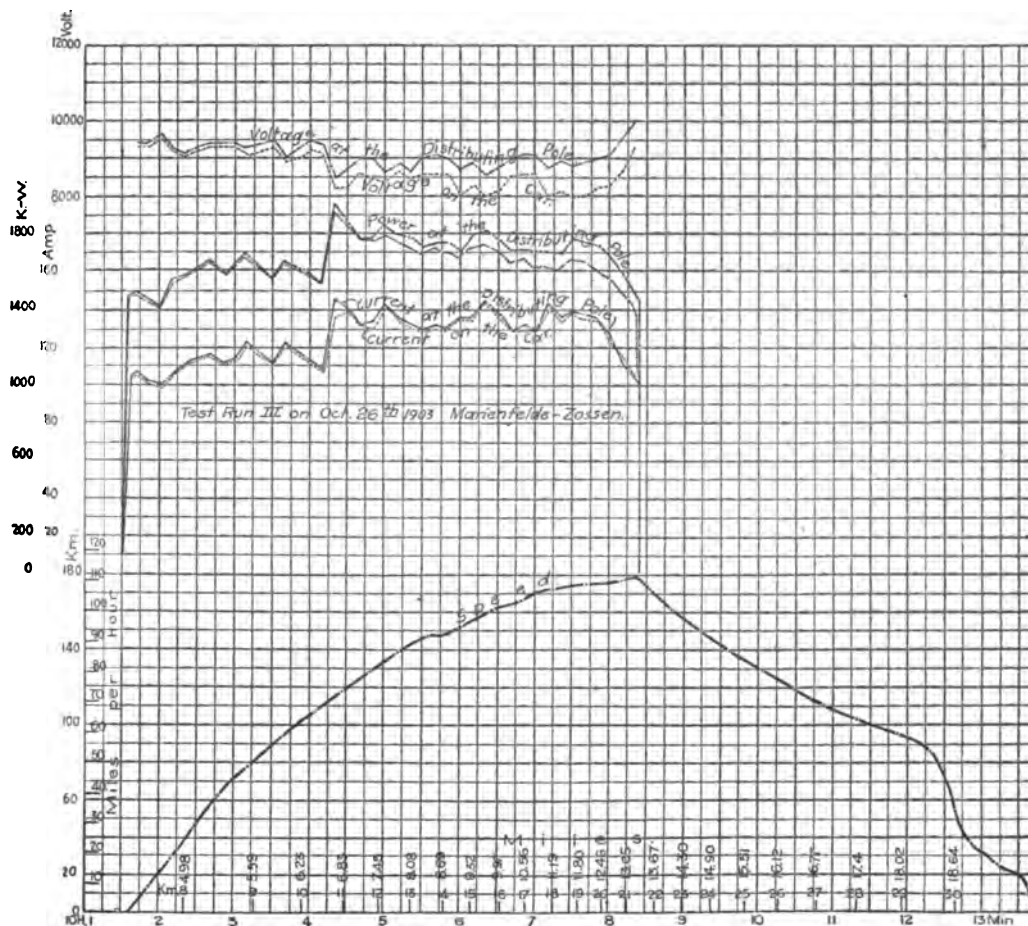


PLATE XXVII.—Test Run with Car "S." Speed, Current, Voltage, Power.

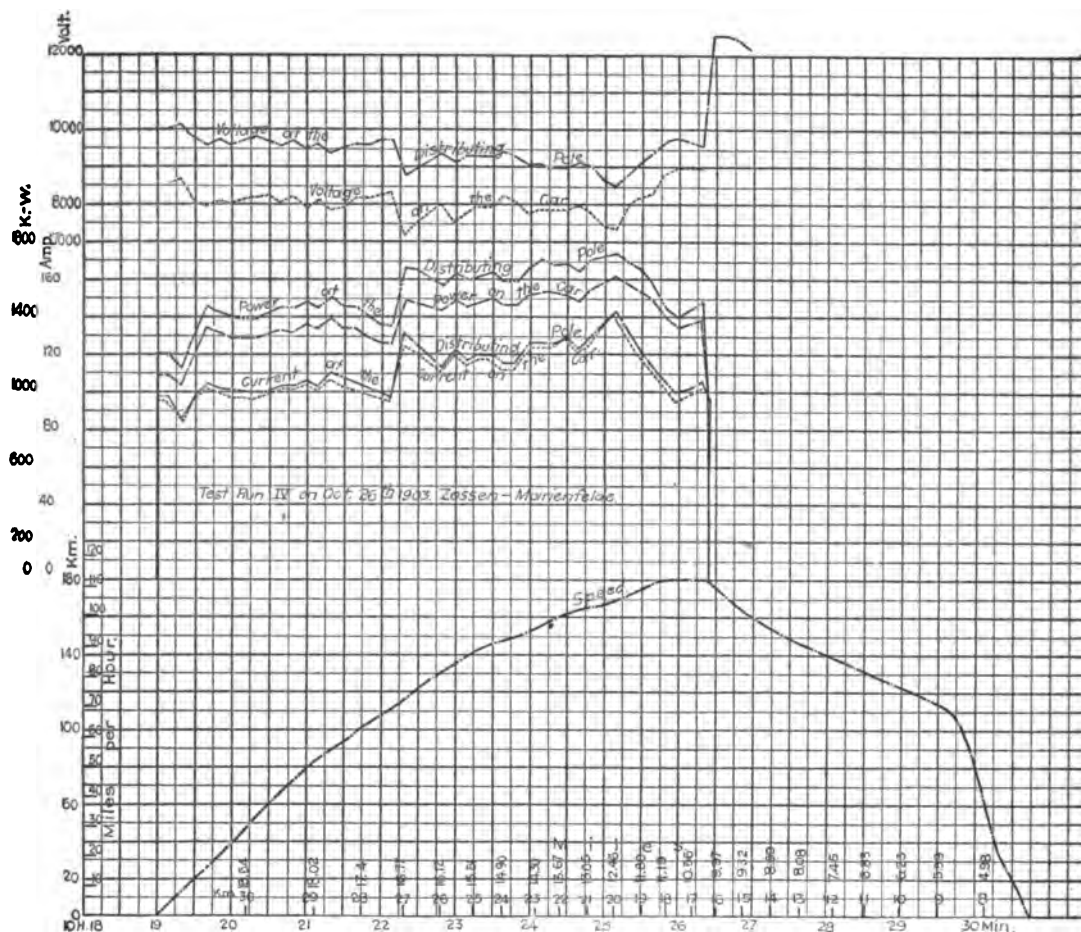


PLATE XXVIII.— Test Run with Car "S." Speed, Current, Voltage, Power.



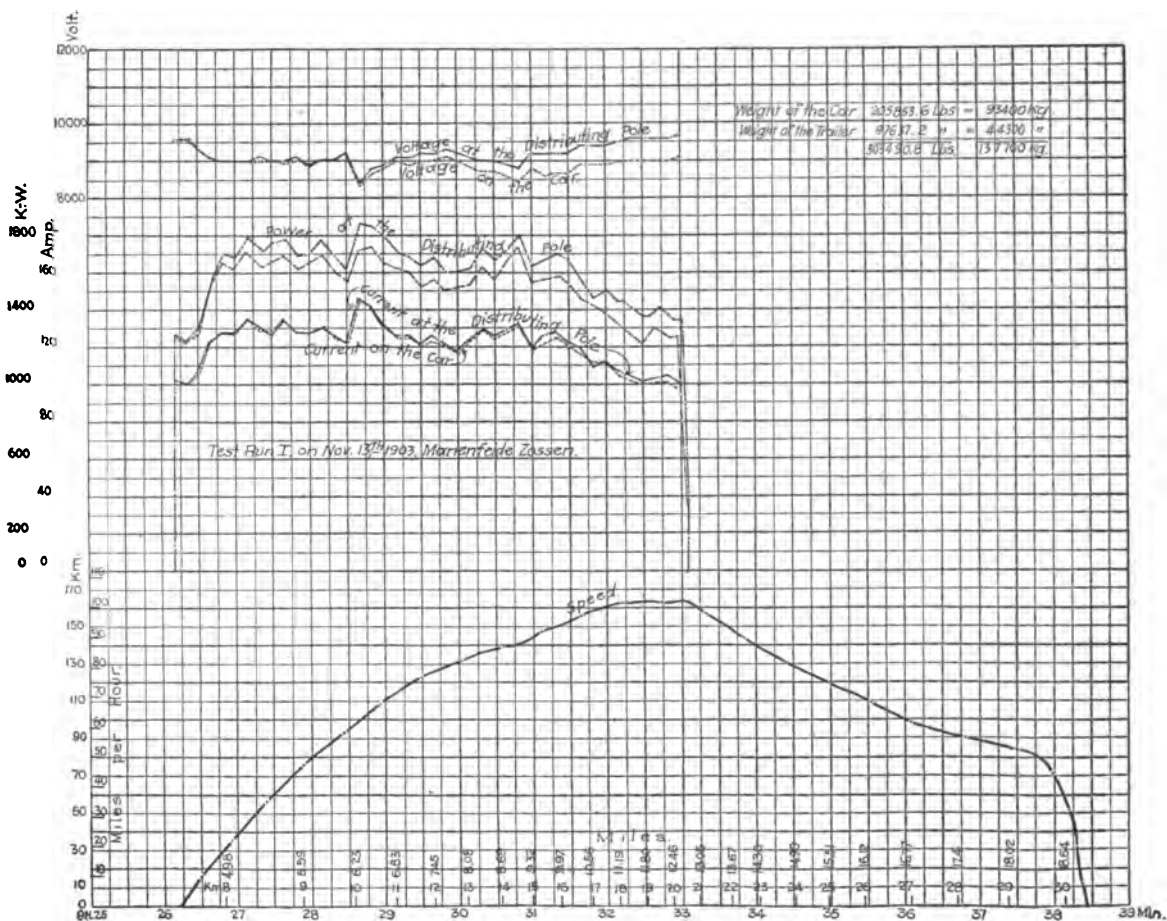


PLATE XXIX.—Test Runs with Car "S" and Six-wheel Double-truck Sleeper. Total Weight. 303,490 lbs. Speed, Current, Voltage, Power.



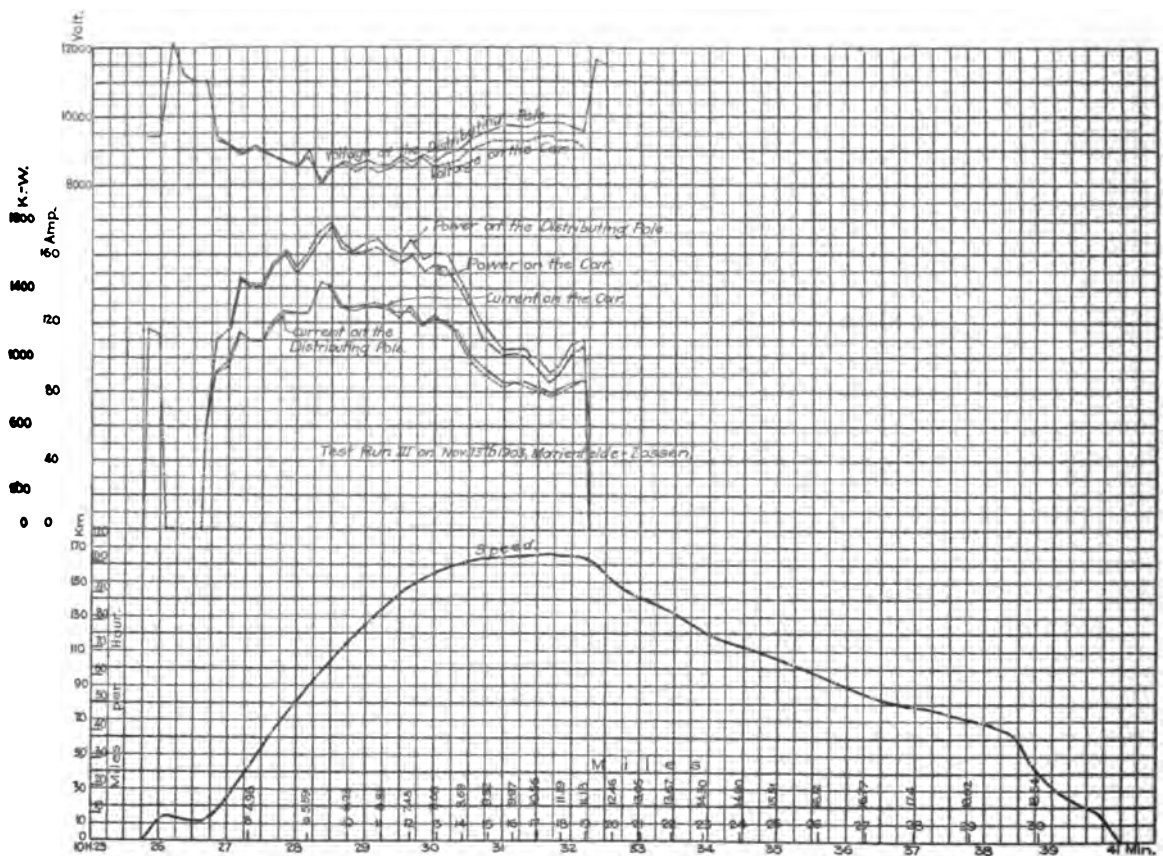


PLATE XXX.—Test Runs with Car "S," without Six-wheel Double-truck Sleeper as Trailer. Speed, Current, Voltage, Power.

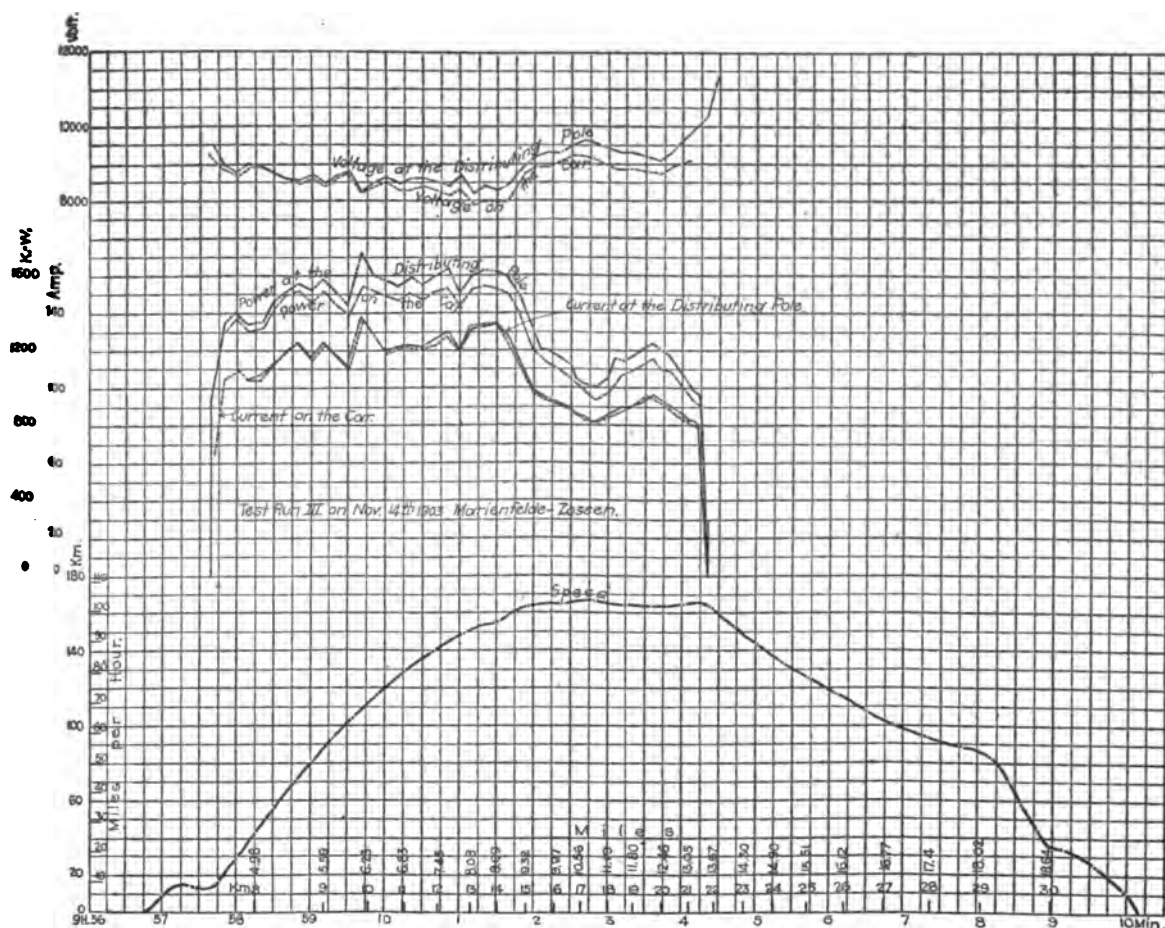


PLATE XXXI.—Test Run with Car 'S.' Speed, Current, Voltage, Power.

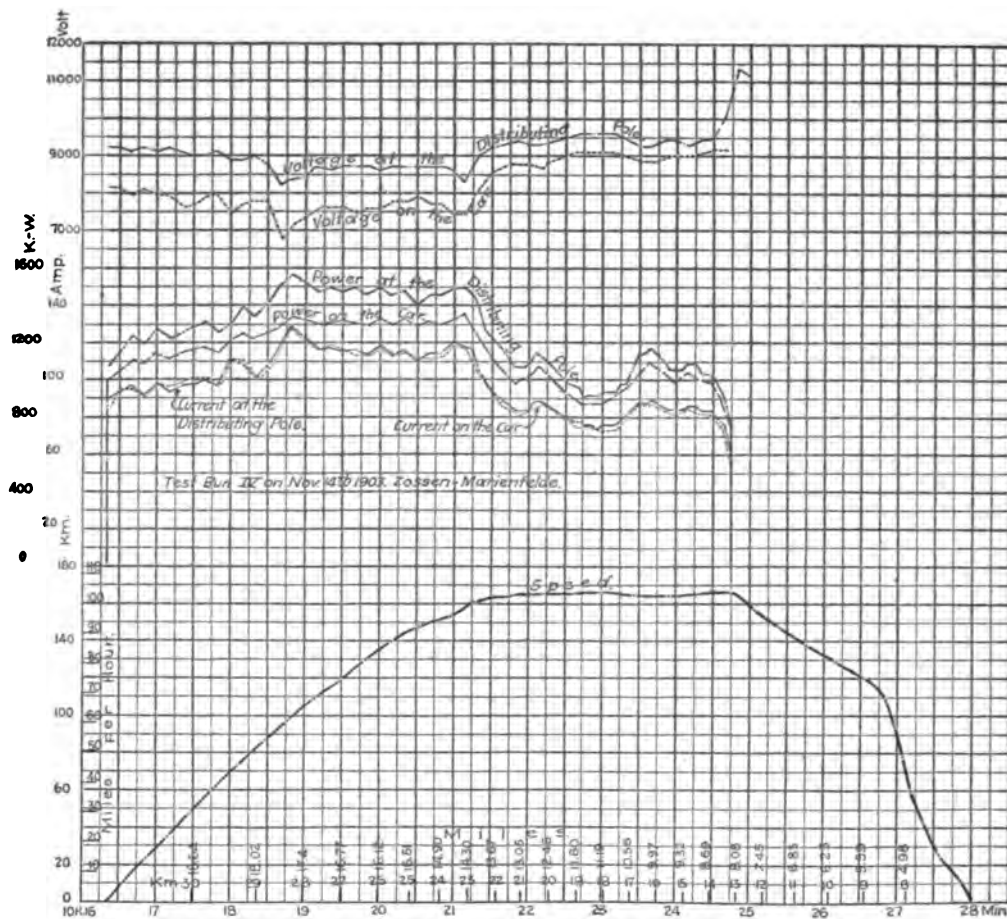


PLATE XXXII.—Test Run with Car "S." Speed, Current, Voltage, Power.

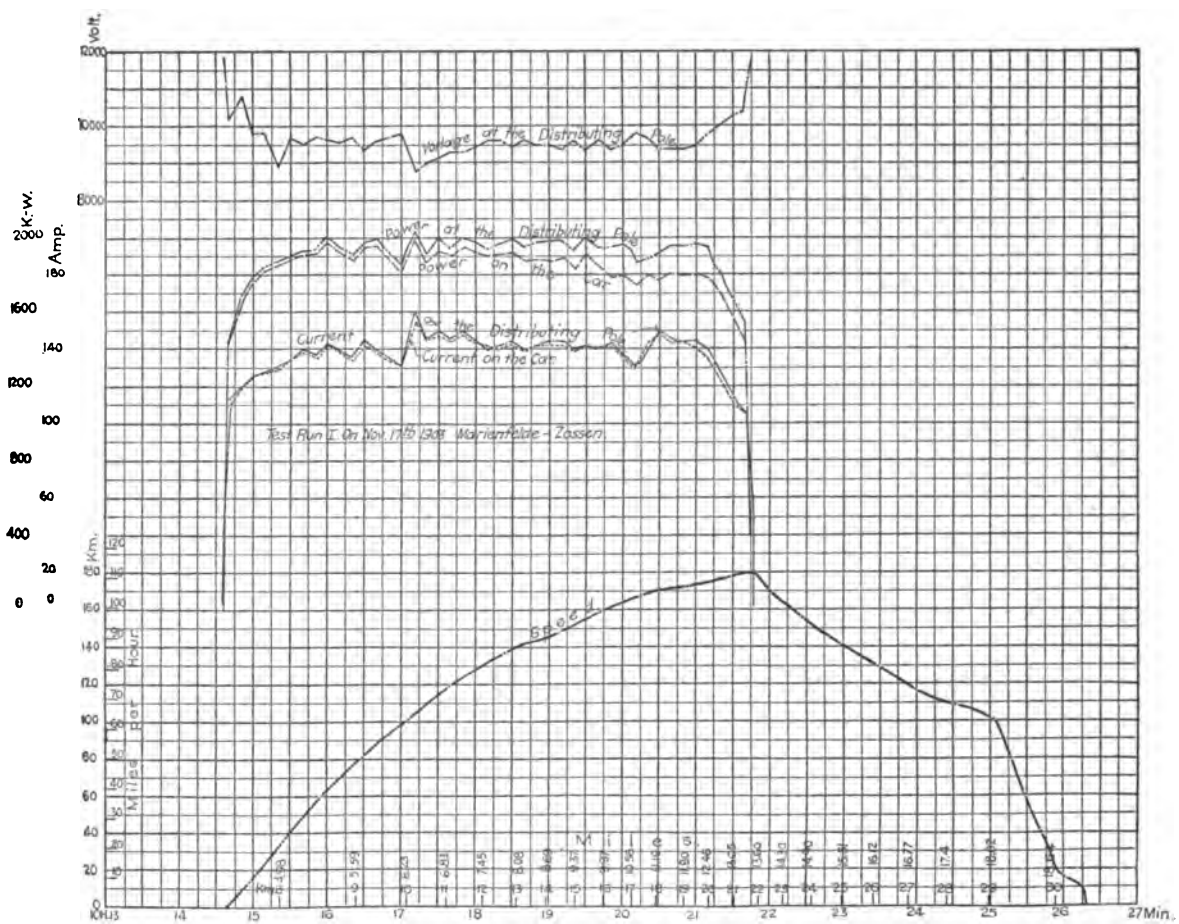


PLATE XXXIII.—Test Run with Car "S" and Six-wheel Double-truck Sleeper as Trailer. Total Weight of Train, 303,490 lbs. Speed, Current, Voltage, Power.

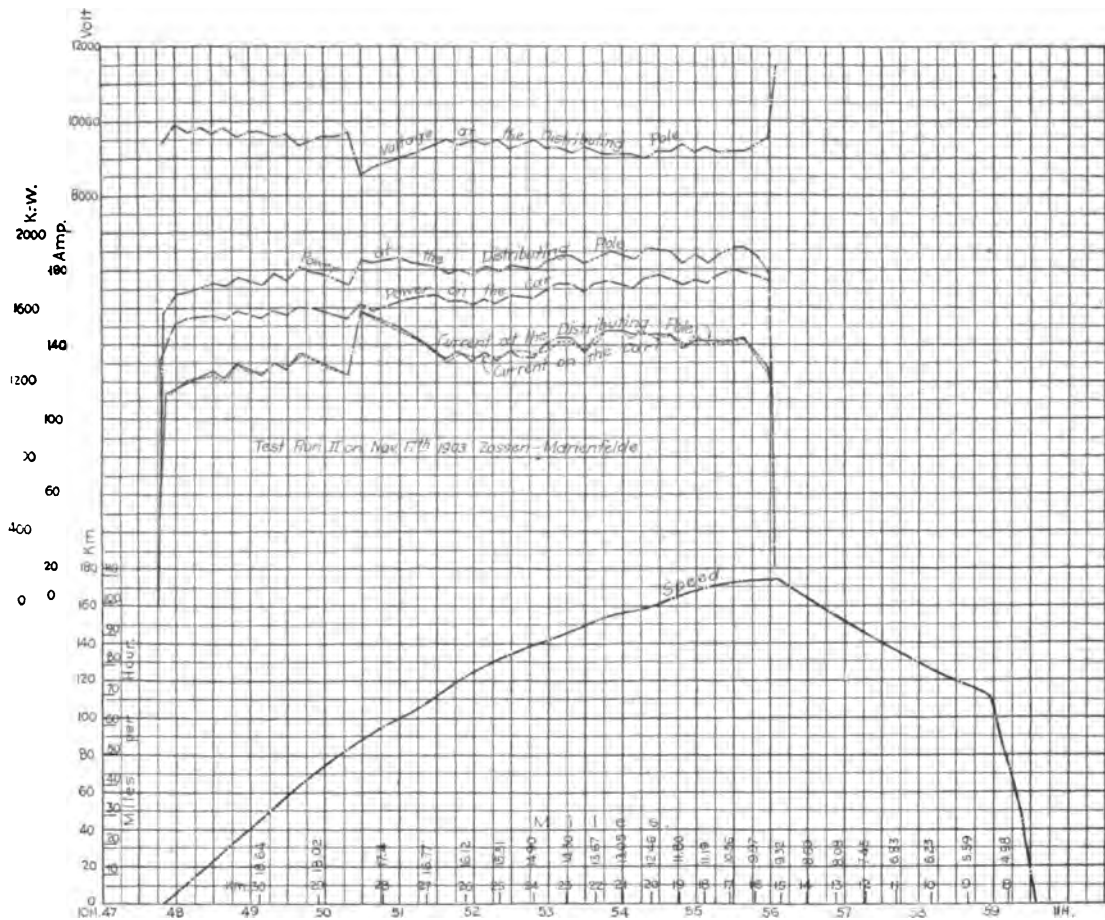


PLATE XXXIV.—Test Run with Car "S" and Six-wheel Double-truck Sleeper as Trailer. Total Weight, 303,490 lbs. Speed, Current, Voltage, Power.

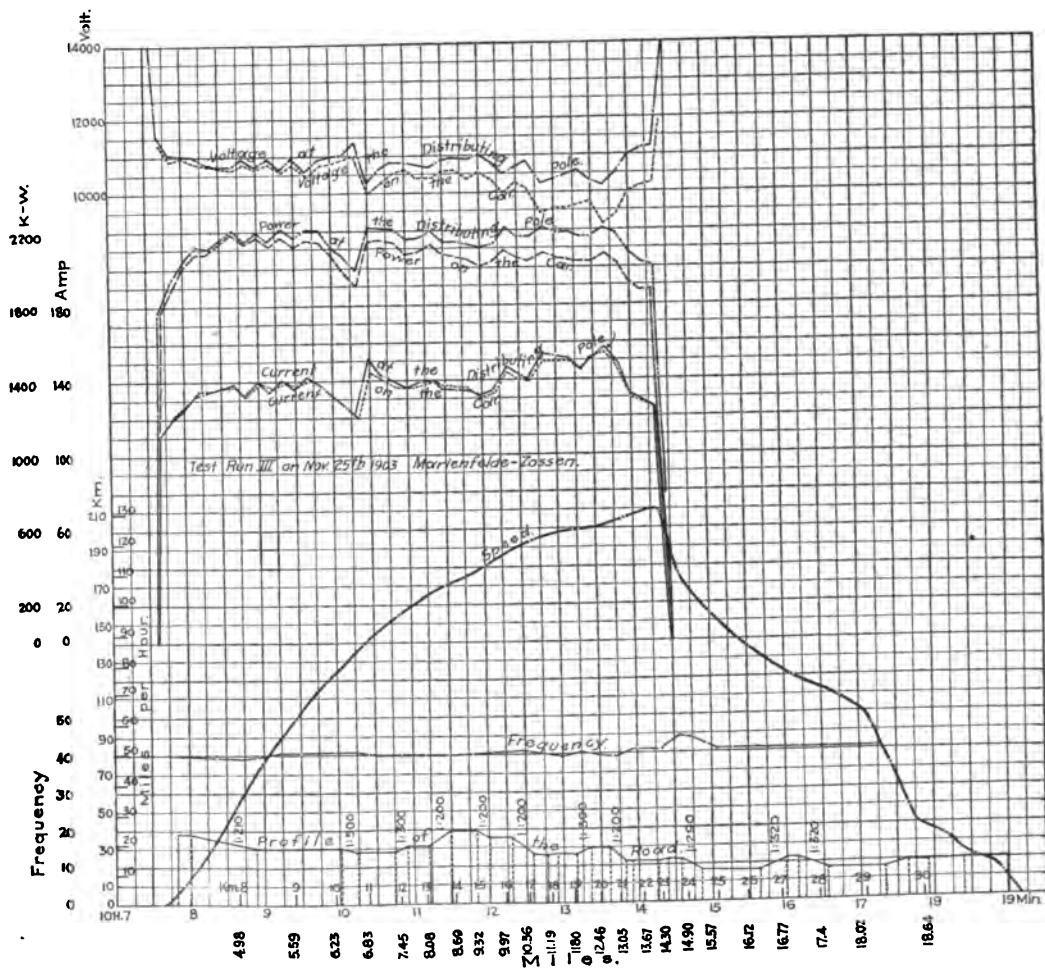


PLATE XXXV.—Test Run with Car "S." Speed, Current, Voltage, Power.

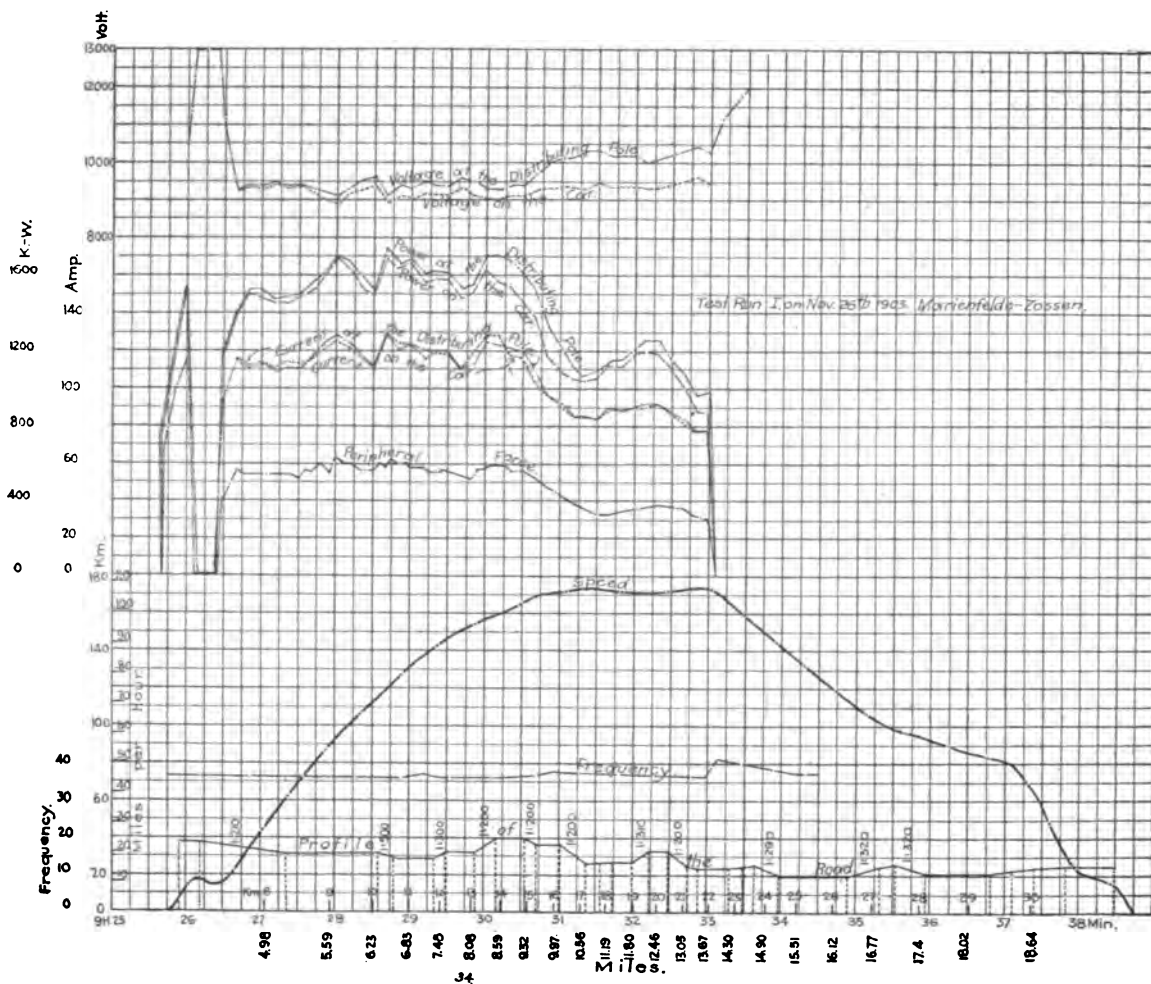


PLATE XXXVI.—Test Run with Car "S." Speed, Current, Voltage, Power.

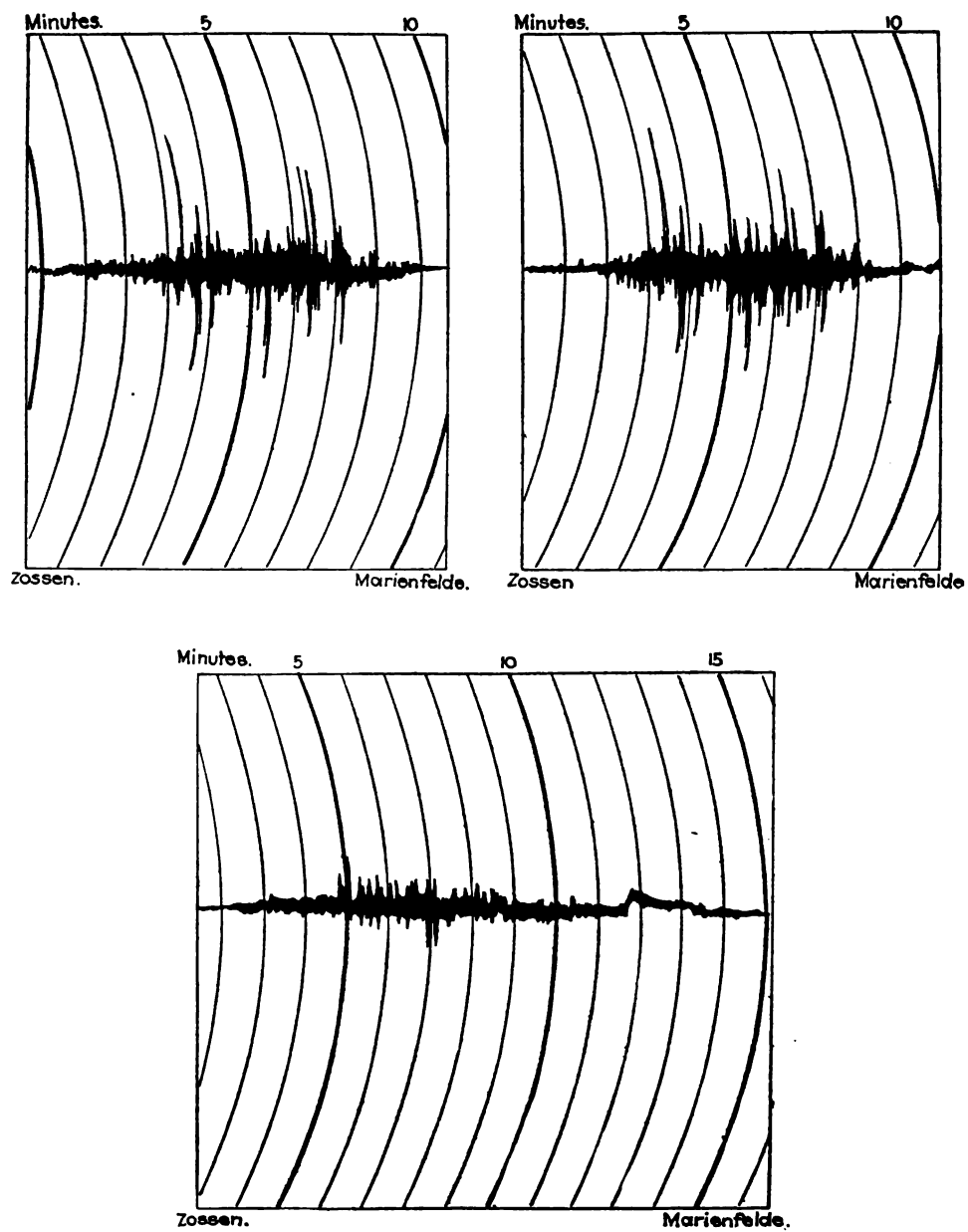
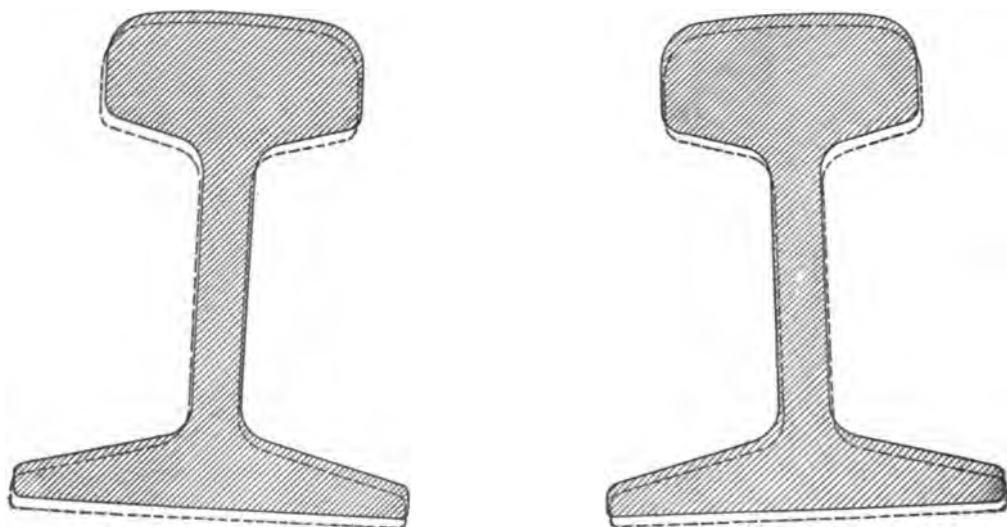


PLATE XXXVII.—Transverse Movements of the Swivel Truck. Two-thirds Actual Size.





**PLATE XXXVIII.**—Measurement of the Track Deformation at the 7.77-mile Post. Speed, 107 Miles per Hour.

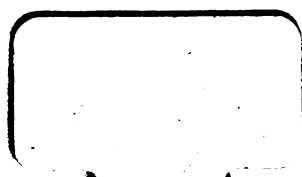




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